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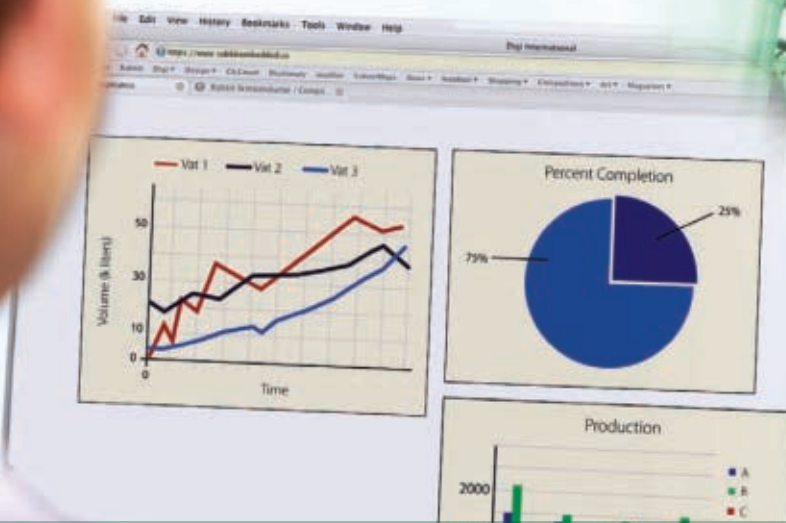
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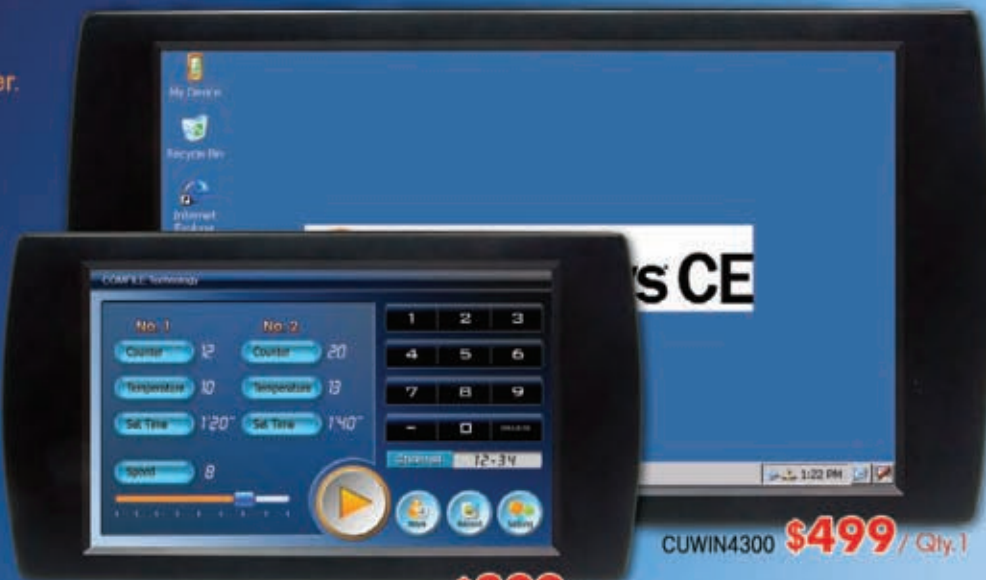


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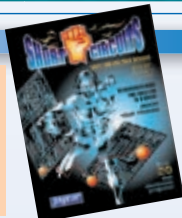
MODEL	CB220	CB230	CB250	CB320	CB380	CB400
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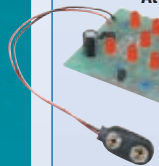


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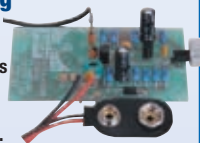
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by Bryan Bergeron, Editor

# DEVELOPING PERSPECTIVES

## To Solder or Not

I finally made the move to a home theater — an Apple TV, DLP projector, and an audio system capable of shaking the foundation. As part of the installation, I also splurged on supposedly audiophile-quality audio cable from a major manufacturer. I don't fall for the oxygen-free cable that sells for astronomical prices but bought some good, 12 gauge copper wire with flexible insulation.

To my dismay, the 'audiophile' cable came with gold-plated twist-on connectors. I was taken aback. Twist-on, not even crimp-on. The instructions said to just peel back a quarter inch of insulation and twist

the wire into a connector. My first response was disbelief. After all, how would a twist-on connector hold up to the constant vibration of a subwoofer? Would the friction fit result in noise?

My second response was to take out my soldering iron and silver solder, and to solder each connection. In the end, the system worked fine, but I was still troubled about the twist-on connectors. Was I just a creature of habit? Was the company just bending to a consumer environment in which soldering irons are becoming an endangered species? Or, I wondered, was I mistaken in my assumptions about the relative value of soldering. Was I wasting my time and effort

with the soldering iron?

As a young ham radio enthusiast, I was taught that, when it comes to high-current DC or any RF connection, use solder, regardless of the connector design. I was told in certain terms that crimp-on connectors were at best short-sighted time savers. Similarly, when I worked for a telephone company, I was taught that wire-wrapped connections would eventually fail unless carefully soldered. Perhaps this line of reasoning was born out of the southern Louisiana environment, where even gold connectors succumbed to corrosion (from an acid-secreting fungus).

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crimp-on connectors, screw-in terminal blocks, and other pressure-based connections. Similarly, the AC wiring feeding many old houses terminates into a screw-in terminal block. But then, are these the 'best' connections possible, or simply the most economical?

The purported benefits of a soldered connection over simply twisting two conductors together — or even professional crimping — include longevity and increased reliability. If you search the web, you'll find numerous discussions on the relative merits of solder and crimping in military avionics. For example, without adequate strain relief, solder joints tend to fatigue, and it takes a relatively high level of skill to properly crimp a multi-pin connector.

However, it's difficult to quantify the value of longevity and increased reliability in ordinary consumer electronics. For example, is it imperative that the soldered connections in your next prototype

outlive you? Similarly, when I look at my computer systems and even my new entertainment system, I can't see past five years. By then, speaker wires will likely be a thing of the past, probably replaced by wireless connections to studio monitors. The computer hardware will be worthless, compared to the computers equipped with 1,000 processor multi-core chips. Perhaps the value of longevity is gravely overstated.

On the value of reliability, I've created thousands of crimped connections, and have yet to see one fail in the field. What I have done is cut back the insulation too aggressively, nicking the underlying copper wire. But this sort of failure is generally immediate, and not something that will surface years later. Furthermore, I can usually prep a wire and place a crimp-on connector faster before my Weller stabilizes at the appropriate temperature.

For now, I'm keeping my

soldering iron handy. Unless I'm working on a prototype, I crimp when possible to get a good physical connection, and then follow up with solder to make it permanent. Perhaps I'm a creature of habit after all.

If you have practical experience, or know of any formal studies comparing soldered and crimped connections, please drop me a line so that I can share your information with other readers. **NV**



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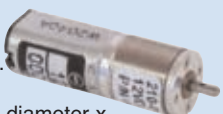
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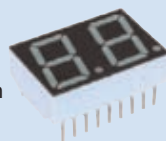
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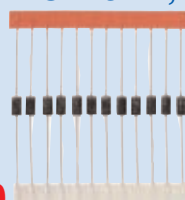
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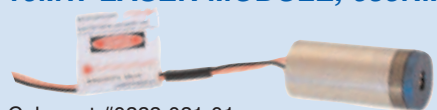
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■ BY JEFF ECKERT

## ADVANCED TECHNOLOGY

### ANTENNA ACHIEVES NEAR-PERFECT PERFORMANCE

PHOTO COURTESY OF VIRGINIA TECH.



■ The compact ultrawideband antenna sans its radome.

Virginia Tech ([www.vt.edu](http://www.vt.edu)) researchers have come up with a compact ultrawideband antenna (CUA) that has potential applications in medical, military, automotive, and home entertainment devices. Most notably, it is said to operate at nearly the theoretical limit on antenna size and performance. According to the official description, the CUA “has at least 10:1 instantaneous bandwidth and nearly constant omnidirectional radiation patterns, high efficiency (>95%), and 5 dBi realized gain over the entire band. In addition, the antenna provides a short pulse radiation characteristic. The electrical size of the CUA is approximately 1/10 wavelength at the lower bound of the band, which is two times smaller than conventional ultrawideband antennas.”

Ultrawideband antennas are designed for a wide range of low energy, short-range transmissions, so this one could prove useful not only for data transmission among

consumer devices but medical imaging systems, automotive collision avoidance, UAVs, and so on.

Information about commercializing the technology is available at the Virginia Tech Intellectual Properties website ([www.vtip.org](http://www.vtip.org)), so feel free to glom onto it.

### NOISELESS AMP DEVELOPED

Researchers at the National Institute of Standards and Technology (NIST, [www.nist.gov](http://www.nist.gov)) and JILA ([jila.colorado.edu](http://jila.colorado.edu)), a joint institute of NIST and the University of Colorado (CU) at Boulder, have announced creation of the first tunable “noiseless” amplifier. Although the concept of noiseless amplification isn’t new, this device is said to offer improved performance and is the first to be tunable (in the range of 4 to 8 GHz). According to an NIST article, “The rules of quantum mechanics say that the noise in amplitude and phase can’t both be zero, but the JILA/NIST amplifier exploits a loophole stipulating that if you measure and amplify only one of these parameters — amplitude, in this case — then the amplifier is theoretically capable of adding no noise. In reality, the JILA/NIST amplifier adds about half the noise that would be expected from measuring both amplitude and phase.”

PHOTO COURTESY OF M. CASTELLANOS-BELTRAN/JILA.



■ The JILA/NIST “noiseless” amplifier.

The device is made up of a long line of magnetic sensors (starting on the right in the photo). The sensors — known as superconducting quantum interference devices (SQUIDs), are composed of aluminum oxide sandwiched between two layers of superconducting niobium, which creates a “metametal” that selectively amplifies microwaves based on amplitude rather than phase. Each amp contains 480 sensors in a 5 mm niobium cavity. An injection of an intense “pump tone” causes the microwave power to oscillate at twice the pump frequency. Only the part of the signal that is synchronous with the pump is amplified.

Practical applications are still in the future, but it is said that the amp could boost the speed and precision of quantum computing, as well as enhancing communication systems.

## COMPUTERS AND NETWORKING

### MONSTER COMPUTING GRID IN OPERATION

The worldwide furor was huge as the first particle beams were injected into the Large Hadron Collider (LHC) in September, but an interesting sideshow is the related Worldwide LHC Computing Grid, which claims the title of world’s largest. The grid combines the power of 140+ computer centers from 33 countries, allowing 7,000 scientists to analyze LHC data. US contributions to the grid are coordinated via the Open Science Grid ([www.opensciencegrid.org](http://www.opensciencegrid.org)), which also works with other scientific research communities including universities, national laboratories, and computing centers across the country.

The grid presently manages more



■ Cables in Fermilab's Grid Computing Center.

than 15 million GB of LHC data annually, and "when the LHC starts running at full speed, it will produce enough data to fill about six CDs per second." The grid allows domestic and foreign research groups to "sift through the LHC data torrent in search of tiny signals that will lead to discoveries about the nature of the physical universe."

As one researcher observed, "We've spent years ramping up to this point, and now, we're excited to help uncover some of the numerous secrets nature is still hiding from us." Watch out Mother Nature. The little carbon-based bugs are tugging at your skirt again.

## SHARPER EYE IN THE SKY

■ Satellite view of Kutztown University, Pennsylvania.



PHOTO COURTESY OF GEO EYE.

If you think the images you get on Google Earth are amazing, wait until you tap into the resources of GeoEye, Inc. ([www.geoeye.com](http://www.geoeye.com)), which on September 6th launched a new imaging satellite, GeoEye-1. Shown in the photo is a shot of Kutztown University, located between Reading and Allentown, PA. The 1856 x 1404 color image would pretty much allow you to count the number of football players on the field and tell a Jeep from a Hummer, which is pretty impressive given that the satellite was moving north to south in a 423 mile high (681 km) orbit at a speed of 4.5 mps when it took the photo. Not so coincidentally, Google ([www.google.com](http://www.google.com)) has its finger in the pie and reportedly will be adding GeoEye to Google Maps and Google Earth, perhaps by the time you read this. For the record, the satellite was built by General Dynamics, and the imaging system was provided by ITT.

## SBC DESIGNED FOR RUGGED ENVIRONMENTS

The Rhodeus, from Diamond Systems Corp. ([www.diamondsystems.com](http://www.diamondsystems.com)), is a fanless PC/104 single-board computer (SBC) that features a 500 MHz AMD Geode LX800 low power consumption processor and up to 1 GB of high speed DDR SDRAM. It is designed to



PHOTO COURTESY OF DIAMOND SYSTEMS CORP.

■ The Rhodeus single-board computer.

operate in harsh environments where airflow for heat dissipation is restricted and heatsinks and fans are unacceptable. It is also intended to perform around-the-clock unattended. Other features include 10/100 Ethernet, two serial ports, two USB 2.0 ports, one parallel port, 1 ATA-33 channel, and a variety of interfaces. It supports Windows 2000, XP, CE 5.0, and Linux. No price was given, but quotes are available online.

## CIRCUITS AND DEVICES

### THE ST-70 STILL LIVES



■ Decades after its birth, the Dynaco ST-70 lives on.

If you're a stereophile beyond the age of 40, you likely remember the Dynaco ST-70, one of the world's most popular stereo amps. The tube-driven device was known for excellent sound quality at a reasonable price and was available in both kit and factory wired versions. Produced in the 1960s and 1970s, Dynaco sold something more than 300,000 of them. The strange thing is that you can still buy a new one, with all new parts, from tubes 4 hi-fi — also known as Vacuum Tube Audio ([www.tubes4hifi.com](http://www.tubes4hifi.com)).

The company is the brainchild of Roy Mottram and has been around since 1988. Roy still has a day job after 20 years of selling these things, so there apparently isn't a gold mine in reproducing vintage audio equipment. But, hey, Christmas is coming up; this would make a great gift for someone who is tired of projects in the digital world.

The stainless steel chassis is identical in size to the original, and



several upgrades make it more reliable and better sounding than the first ones. You even get a choice between classic or high gain models. Alas, there is a downside: It will run you \$595 plus shipping. And that doesn't include the tubes, which add \$79. Ouch! But think how nifty it will look next to those IC-driven, plastic-boxed Taiwanese components.

### THREE-IN-ONE CURSOR CONTROLLER

If you're looking to replace a stationary mouse or trackball in a new design or piece of existing equipment, take a look at Grayhill's new Series 60C controller. The three-in-one multifunction cursor control device integrates an optical encoder, joystick, and pushbutton onto a concentric shaft, making it particularly useful for dashboards and anywhere the use of separate joysticks,

encoders, and pushbuttons is impractical. It provides the functionality of a stationary mouse or trackball in a 1"x1"x 0.661" deep package. The joystick manipulates a cursor left, right, up, and down; the rotary encoder facilitates sequential scrolling through menu options; and the pushbutton performs on-screen menu selects. Termination is via a cable/connector assembly, and single piece pricing starts at \$29.89. For details, visit [www.grayhill.com](http://www.grayhill.com).

### TWEEZER PROBE SIMPLIFIES MEASUREMENTS

A handy product from our neighbors to the north is Smart Tweezers, sold by Siborg Systems ([www.siborg.com](http://www.siborg.com)). It's basically an LCR meter in a set of tweezers, with built-in high precision SMD probes and a display. It's designed for component evaluation on a PCB

or production line, component impedance testing, and sorting of SMD components. Measurement ranges are 0.1 ohm to 5 Mohm, 10 pF to 499  $\mu$ F, and 1  $\mu$ H to 1 H. You also get voltage measurements up to 8 VDC. The latest model comes with an inductive charger that keeps the internal rechargeable batteries fresh and virtually eliminates the need for battery replacement.

For more information, visit [www.siborg.com](http://www.siborg.com). For purchase, be ready to shell out US \$314.99. **NV**

■ Various models of Siborg's tweezer probes.



## INDUSTRY AND THE PROFESSION

### COMPUTER BUG SPREADING

Early this year, reports began to surface about a new type of bug that is destroying computers and other electronic equipment. But, in this case, we're talking about a real insect known as the "crazy raspberry ant." Crazy because they seem to move randomly as opposed to marching in regimented lines, and raspberry because they were first identified by Tom Raspberry, an exterminator.

Believed to have stowed away on a boat from the Caribbean, so far they have migrated to only about six Texas counties in the Houston area, where

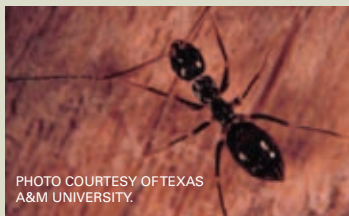


PHOTO COURTESY OF TEXAS A&M UNIVERSITY.

■ Crazy ant, *Paratrechina longicornis*.

they seem to like the weather. On the positive side, they kill the dreaded fire ants. On the negative, they suck moisture from plants, feed on beneficial insects like ladybugs, and eat the hatchlings of Attwater prairie chickens. But the most interesting characteristic is that they are inexplicably attracted to electrical equipment, where they feast on insulation and cause short circuits. This is not viewed as a humorous situation at places like NASA's Johnson Space Center and the Houston Airport. The crazy ants are difficult to kill, as they have multiple queens in each colony and don't seem to mind over-the-counter insecticides. Research on what to do about the problem is being conducted by Texas A&M University, the EPA, and the Texas Dept. of Agriculture with the assistance of Mr. Raspberry himself. For updates, visit Tom's website, [ww.281deadbug.com](http://ww.281deadbug.com).

### IEEE MEDAL OF HONOR AWARDED

On Sept. 20, the Institute of Electrical and Electronics Engineers ([www.ieee.org](http://www.ieee.org)) awarded its 2008 Medal of Honor to Gordon

Moore, co-founder and chairman of the board, emeritus, at Intel Corporation. The IEEE cited his contributions to the advancement of semiconductor technology, both as an engineer and

entrepreneur, and for helping to shape the global electronics industry. At a ceremony held in Quebec City, Canada, the institute also bestowed its Corporate Innovation Recognition award to Research in Motion Ltd. for developing and promoting the Blackberry and helping to transform the mobile work environment. In a statement, the IEEE said, "As a result of [the honorees'] achievements, smartphones allow employees to keep in contact while on the road, computers are equipped with memory that allows us to store and erase documents, 3D imaging is helping healthcare professionals to treat their patients like never before, and the continuing development of advanced computing technologies drives new solutions for a broad spectrum of global concerns."

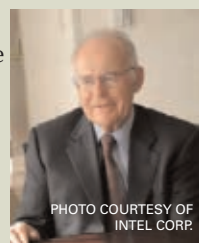


PHOTO COURTESY OF INTEL CORP.  
■ Award winner Gordon Moore.



# Scalability reaches 1Mbyte with 100MHz single cycle embedded Flash.

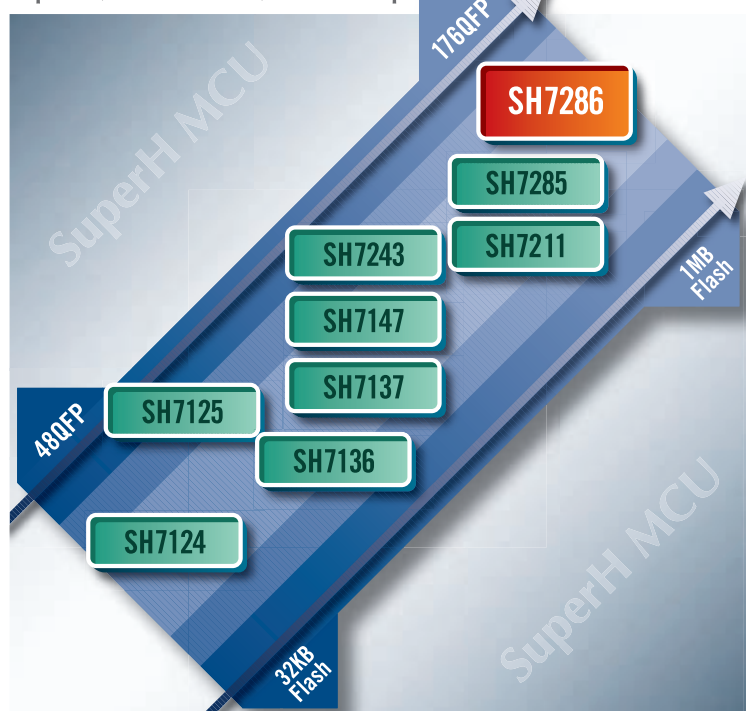
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SuperH (SH2 and SH2A) MCU lineup



\*Source: Gartner "Semiconductor Applications Worldwide Annual Market Share: Database" Hiroyuki Shimizu, 27 March 2008, GJ08218 \*This is 2007 ranking

HOT Products	SH7286
--------------	--------

SH2A CPU Core	
MONOS Flash (1MB)	RAM (up to 32KB)
External Bus Interface (BSC)	DMA+DTC
Timer MTU2 (6ch)	Timer MTU2S (3ch)
Timer CMT (2ch)	Watchdog Timer
SSU+I <sup>2</sup> C	SCI x 5
USB Function	CAN
On-Chip Debug	A/D x 3 (12ch)
176pin	

### Top Reasons to Select SH7286

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Starter Kit for SH7286:  
R0K572867S000BE;  
includes USB debugger

Renesas Technology Corp.



■ BY FRED EADY

## AVOIDING TUITION AT USB UNIVERSITY

**I HAVE A LOVE/HATE RELATIONSHIP WITH USB. I love it because it is convenient and user friendly. I hate it because understanding the underlying processes of USB can be difficult. Think about this. You don't have to know the down and dirty details of how a PIC ALU (Arithmetic Logic Unit) works to employ a PIC in a microcontroller-based application. So, why should we have to know so much about USB to put it to work for us?**

I'm obviously not alone when it comes to wondering why deploying USB in an embedded application has to be so darned complicated. The war began when personal desktop computers and laptop computers dropped the RS-232 interface for multiple USB interfaces. Microcontroller manufacturers such as Microchip, Texas Instruments, and Atmel stepped in and offered lines of microcontrollers with built-in USB engines and embedded USB interface devices. Microchip is still on the front line of the embedded RS-232-to-USB revolution.

A USB firmware package called USB Framework is available for download from Microchip. The Microchip USB development package extends from the PIC18F eight bit microcontrollers up through the PIC24F 16 bit microcontrollers and out into 32 bit space with backward compatible USB API extensions designed for the 32 bit PIC32. Officially, the Microchip USB tools are packaged as the MCHPFUSB Framework for the eight bit and 16 bit PIC microcontrollers. The MCHPFUSB Framework opens up PIC18F and PIC24F projects, drivers, and PC-based resources. The MCHPFUSB USB stack is API compatible with its 32 bit counterpart, the USB Device and Embedded Host Stack for PIC32.

Other microcontroller manufacturers tackled the lack of PC RS-232 port access by introducing USB-to-UART bridge integrated circuits. For instance, FTDI (Future Technology Devices International) has a full line of RS-232 converter replacement integrated circuits. The FTDI RS-232/USB ICs do everything necessary to build a data link between a USB device and a microcontroller UART. Most of the FTDI parts also contain additional user-accessible I/O pins. The latest FTDI device — the FT232R USB UART IC — can internally generate a clock that is suitable for driving an external host microcontroller. The FT232R doesn't leave any USB hardware loose ends. The clock generation is performed on-chip and no external crystal is required. All of the USB termination resistors are

also fully integrated on-chip. The FTDI engineers thought of everything including on-chip power conversion and transmit and receive LED drive signals. USB likes to “describe things.” So, the external EEPROM that normally holds some of the USB descriptions has been incorporated into the bowels of the FT232R.

If you don't need the extra I/O and only want to convert the interface from RS-232 to USB, Silicon Labs offers the CP2102 Single Chip USB-to-UART Bridge. Like the FTDI FT232R, the CP2102 pulls the USB clock, termination resistors, 1024 byte EEPROM, and power conversion down to the chip level.

All of the aforementioned USB conversion ICs are supported by free PC drivers that are supplied by each of the USB-to-RS-232 converter IC manufacturers. With the USB hardware distilled into a single IC and free PC driver software, the only USB deployment obstacle we may possibly see as hobbyists is soldering down the very small USB IC SMT packages. You can overcome the SMT soldering obstacle in your development phase by purchasing preassembled USB modules from FTDI and DLP Designs.

Thus far, we've only discussed the replacement of RS-232 converter ICs with spiffy USB interface ICs. Sure, easily getting a PIC's UART to communicate directly with a PC's USB port is a step forward. However, if we design in a dedicated USB-to-UART bridge IC, we're only going to be able to communicate in the same manner (UART-to-PC terminal emulator) as the RS-232 circuit we replaced. That is not a bad thing if all we need to do is replace the RS-232 interface on our embedded device. What if we wanted to interface our embedded creation with another USB device other than a PC?

---

### VINCULUM

---

Vinculum, as defined by the Merriam-Webster dictionary, originates from the Latin vincire, which means

to bind. FTDI's Vinculum USB Host Controller IC (VNC1L) is actually a microcontroller with 64 KB of embedded Flash program memory that encapsulates USB device classes. In addition to hosting the USB device classes, the VNC1L takes care of the USB Host Interface and data transfer functions. If that isn't enough binding of technology for you, Vinculum series ICs automatically handle the FAT12, FAT16, and FAT32 file systems.

I don't know about you, but I'm not really worried about what's inside a VNC1L. The question is: can I use a VNC1L without going to the University of USB? An initial read of the VNC1L datasheet tells me that I have access to a pair of USB 2.0 compliant host/slave ports. The whole idea here is to put a PIC on the host side of a USB wire and it looks like I can interface my microcontroller to the VNC1L using the microcontroller's UART, the microcontroller's SPI interface, or the microcontrollers' parallel FIFO interface.

Okay, I'm hooked in. Let's see if we can make the VNC1L do some USB tricks without having to resort to the USB encyclopedia. My VNC1L-laden VDIP2 development board can be seen in Photo 1. The VDIP2 is simply a carrier for the VNC1L. As you can see in the photo, the VDIP2 is packaged in a 40 pin DIP form factor. The standard pin spacing of the VDIP2 gives us easy prototyping access to all of the VNC1L's resources. The VDIP2 is represented graphically in Schematic 1.

The VNC1L datasheet and supporting documentation tell us that the VNC1L is really a specialized USB microcontroller with loads of built-in USB functionality. Reading further into the datasheet reveals the fact that various supervisory applications can be loaded into the VNC1L's Flash program memory. The VDIP2 comes from the factory preloaded with Vinculum VDAC supervisory firmware. This VDAC firmware allows the VNC1L to interface a disk device and USB slave peripheral to the VDIP2's pair of USB ports. In this case, a disk is defined as a BOMS (Bulk Only Mass Storage) Flash Disk, which is just another way of saying USB memory stick or thumb drive. Keyboards, mice, and printers fall into the USB slave peripheral category.

As you can see in Schematic 1, the VDIP2 circuitry isn't complex at all. The USB interface is pretty much self-explanatory. However, there are VNC1L pins that perform functions that aren't posted in their schematic symbols.

For instance, driving the PROG# pin low and toggling the RESET# pin high-low-high enables the VNC1L bootloader mode with a UART programmer interface. When not in bootloader mode, the ACBUS5 and ACBUS6 pins determine the VNC1L's command monitor interface. Pulling up both ACBUS5 and ACBUS6 selects UART interface mode. UART interface mode can also be selected by pulling ACBUS5 and ACBUS6 logically low. ACBUS5 pulled logically low with ACBUS6 pulled logically high puts the VNC1L's command monitor interface into SPI mode. Reversing the SPI mode logic pattern on ACBUS5 and ACBUS6 enables the command monitor parallel FIFO interface. In UART interface mode, pins ADBUS0 and ADBUS1 become the UART TXD and RXD lines, respectively.

When the SPI command monitor interface is active, the ADBUS0 pin becomes SCLK (Clock) and the ADBUS1 pin serves as SDI (Data IN). SDO (Data Out) duty falls to the ADBUS2 pin and the ADBUS3 pin becomes the SPI SS pin (Slave Select). Knowledge of how the VNC1L's pins morph is only half of the picture. To fully utilize the power of the VNC1L, we will need to walk the road of firmware understanding.

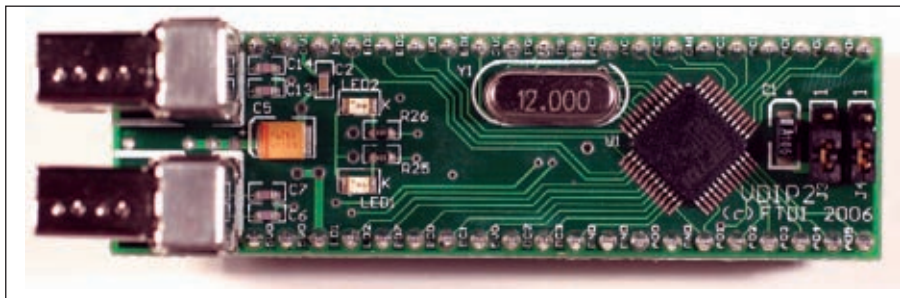
## THE SOFT SIDE OF VINCULUM

In the midst of the Vinculum pinout conversation, I threw out the words "command monitor." It might be a good idea to begin our Vinculum firmware discussion with a definition of this phrase. Basically, the command monitor is a firmware entity that is used by a microcontroller to send and receive data and commands to the VNC1L. In a similar manner to PC DOS command windows, the VNC1L command monitor issues a prompt to the microcontroller informing it that the command monitor is ready for the next command. The command monitor responds to commands from the microcontroller by issuing status and error information just as a PC DOS command window would.

The VNC1L documentation can be confusing when it comes to the word "monitor." So, let's see if I can prevent the confusion this may cause you if you decide to read the VNC1L datasheet and firmware guide. The command monitor is a part of the Vinculum firmware that runs in the VNC1L's internal microcontroller. A monitor is the

hardware device that sits at the other end of the VNC1L firmware's command monitor code module. In our case, the monitor is a PIC. The VNC1L documentation will sometimes leave the word command out of a command monitor discussion and simply call the command monitor a monitor.

The manner in which the microcontroller interfaces with the command monitor (UART, SPI, FIFO) is determined by VNC1L pins ADCBUS5 and ADCBUS6. The pins that support



■ PHOTO 1. The VDIP2 is designed to be plugged into a 40-pin IC socket. The VDIP2's pins provide direct access to the VNC1L's UART, parallel FIFO, and SPI interfaces.



the UART, SPI, and FIFO interfaces make up what is termed the combined interface.

There are currently six precompiled Vinculum supervisory firmware versions:

- VDAP      Disk and peripherals

- VDIF
- VMSC
- VDPS
- VCDC
- VDFC

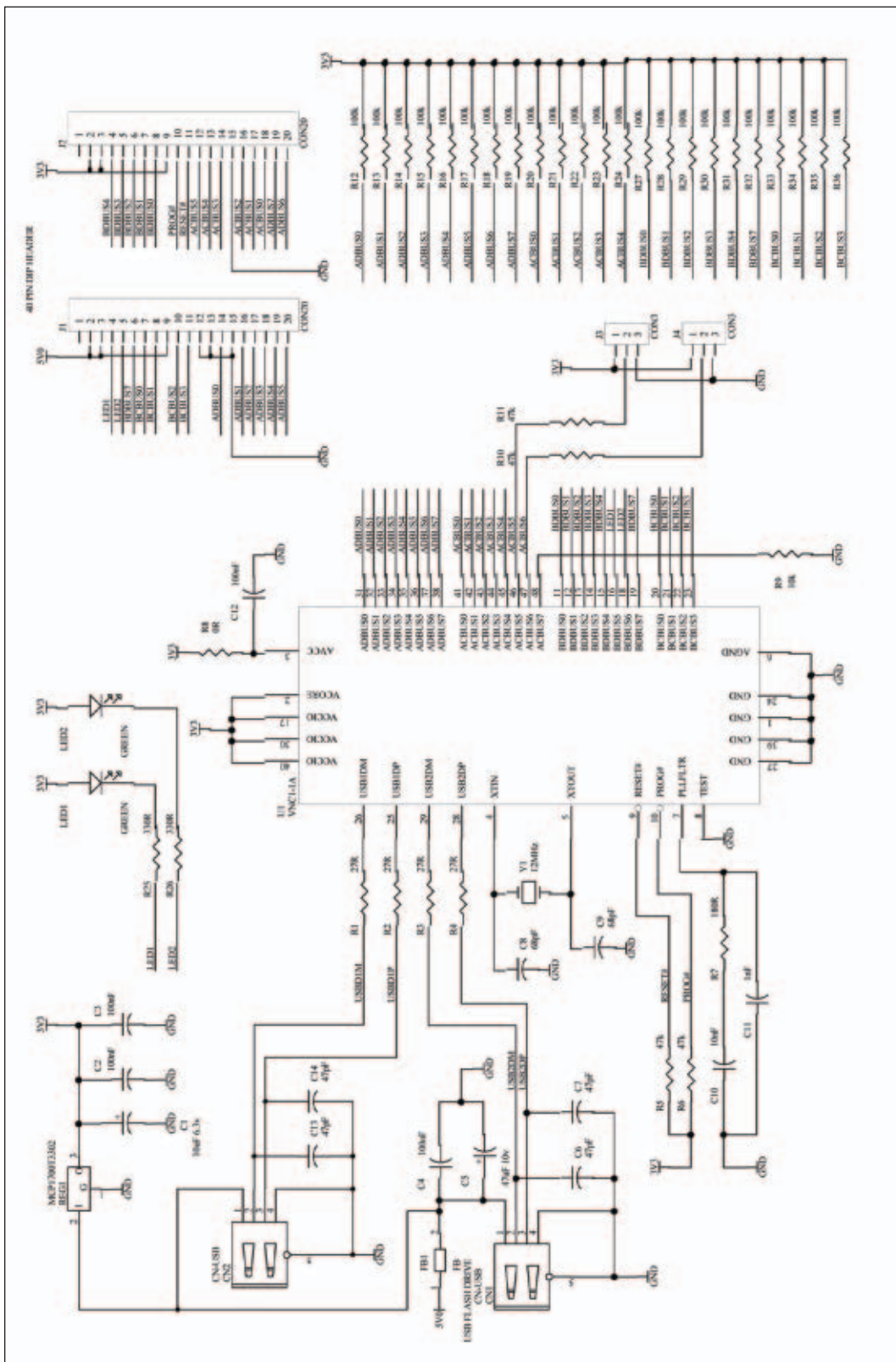
- Disk and FTDI interface
- Music player
- Disk, PC monitor, and slave port
- Communication class device
- Disk and file copier

My VDIP2 is loaded with VDAP, the general-purpose firmware loads and supports USB devices on USB ports 1 and 2 with the exception of the USB BOMS device, which is only supported on USB port 2. The VDAP command monitor communicates with the monitor device using one of the interfaces that make up the combined interface.

The VNC1L's command monitor operates in two modes. Data mode is used to pass information from the command monitor directly to another device on USB port 1 or USB port 2. To communicate with the VNC1L's command interpreter, Command Mode must be invoked. The DATAACK# and DATAREQ# pins (the # means that the pin is active low) are used to switch between Data Mode and Command Mode.

The VNC1L firmware will start in Command Mode. The DATAACK# and DATAREQ# pins need to be held logically high at firmware start to assure

■ **SCHEMATIC 1.** Looks very similar to an everyday USB-enabled microcontroller circuit, doesn't it? Well, it is... sorta. However, we don't have to write a single byte of supervisor code. Several different FTDI-supplied, application-specific firmware images can be loaded into the VNC1L. All we need to do is to integrate a PIC into this picture.



that the VNC1L supervisory firmware will remain in Command Mode. The UART monitor interface can be configured while in this mode. In addition, an FTDI USB slave UART device attached to USB port 1 can be configured while Command Mode is active. Examples of supported FTDI USB slave UART devices include the FT232, FT245, and FT2232.

Data Mode is invoked when the DATAREQ# pin is pulled logically low. In Data Mode, any data sent to the monitor port will be sent to a slave USB device on USB port 1 or USB port 2. Conversely, data from a USB slave device will be directed to the monitor port. In our case, the fish with its mouth open at the monitor port will be our PIC microcontroller.

I would like to see all of the VNC1L's VDAP functionality first hand. I think you would too. So, let's put a plan together for the supporting hardware.

## THE HARD(WARE) SIDE OF VINCULUM

The VDIP2 makes the monitor hardware design pretty easy as most everything we need to interface to an external USB device is already soldered down on the VDIP2 prototype board. Despite the completeness of the VDIP2, there is some hardware work that we'll need to perform. For instance, we'll still have to accommodate the UART interface between the VNC1L and the PIC. It also looks like we'll have to choose a suitable PIC microcontroller that can operate with a 3.3 VDC power source. The VDIP2's on-board MCP1700 LDO voltage regulator has an extra 200 mA on its hands. So, we'll tap into the VDIP2's surplus regulated power source to fuel our PIC.

Our VDIP2 companion hardware will also include the capability of the PIC to put the VDIP2's VNC1L into bootloader mode. Who knows, we may need to reload VNC1L firmware through the VNC1L's UART bootloader portal. We'll also tap into the VNC1L's DATAACK# and DATAREQ# lines to facilitate switching the command monitor between Data and Command modes.

Working out the hardware interconnect details will be a walk in the park compared to coding up the monitor device firmware. So, let's take a look at what it's going to take on the software side to talk to the VNC1L via the common interface.

## CODING THE MONITOR

The VNC1L can't function without a monitor at the other end of the command monitor software interface. The simplest form of monitor is a PC running a terminal emulator. However, that's not why we're here. The idea is to add USB host functionality to a PIC microcontroller. One of my goals is to interface a PIC to a thumb drive.

So, let's put some support functions together that we'll use to read and write to a thumb drive.

The VNC1L's command monitor interface supports a pair of command entry modes. The command entry mode determines how the VNC1L displays prompts and the

entry format of commands. When the command monitor is in Extended entry mode, printable ASCII characters are used for prompts and in the body of commands. Short entry mode is designed to reduce the overhead of prompting and command entry when a resource-constrained application is interfacing with the command monitor. Commands in Short entry mode are represented in binary. Upon reset, the command monitor defaults to Extended entry mode.

Regardless of the command monitor entry mode, we must code up some routines to send and receive characters from our PIC's UART. Sending commands and data is always under the control of the PIC. So, all we need are simple transmit routines. Here's a basic UART transmit routine that simply transmits a single character:

```
char sendchar(char usart_data) {
    unsigned char tmphead;
    // calculate buffer index
    tmphead = (EUSART_TxHead + 1) & EUSART_TX_BUFFER_MASK;
    // wait for free space in buffer
    while ( tmphead == EUSART_TxTail );
    // store usart_data in buffer
    EUSART_TxBuf[tmphead] = (unsigned char)usart_data;
    // store new index
    EUSART_TxHead = tmphead;
    // enable TX interrupt
    TXIE = 1;
    return usart_data;
}
```

The sendchar function uses the resources of an interrupt handler and a transmit buffer to transmit a character. The sendchar function works very well for character-based communications sessions. However, choosing to employ the sendchar function when the command monitor is in Extended entry mode may cause mogigraphia (writer's cramp or, in this case, programmer's cramp). So, when it's logical to do so, we will use standard C printf statements to convey commands while the VNC1L is in Extended entry mode. For instance, one of the VNC1L commands simply requests the echoing of the ASCII characters 'E' or 'e'. Here's the command sequence to send an E using the sendchar function:

```
/* *****
/*      ECHO Command
/*      Send "E" or "e" plus carriage return
/* *****
sendchar(0x45); //transmit 'E'
sendchar(0x0D); //transmit carriage return
```

Now, here's a printf-based function that can send E or e:

```
/* *****
/*      ECHO Command
/*      Send "E" or "e" plus carriage return
/* *****
void cmd_echo(char cmd)
{
    printf("%c\r", cmd);
}
```

We can't always count on knowing when the VNC1L



will send a character to the monitor. So, to be sure that we don't miss any of the VNC1L's transmissions, our

UART receive mechanism will be buffered and interrupt driven. All we will need to put a fool-proof receive engine in place is a means of determining if a character has been received and a receive interrupt routine that will buffer the incoming characters until we are ready to process them. The interrupt handler code snippet that follows handles pulling the incoming characters from the UART's receive buffer into the PIC's receive buffer:

```
if(RCIF) {
    // read the received usart_data
    usart_data = RCREG;
    // calculate buffer index
    tmphead = (EUSART_RxHead +1) & EUSART_RX_BUFFER_MASK;
    // store new index
    EUSART_RxHead = tmphead;
    // store received usart_data in buffer
    EUSART_RxBuf[tmphead] = usart_data;
}
```

Once a character is processed into the PIC's receivebuffer, we can check for its presence with a call to this function:

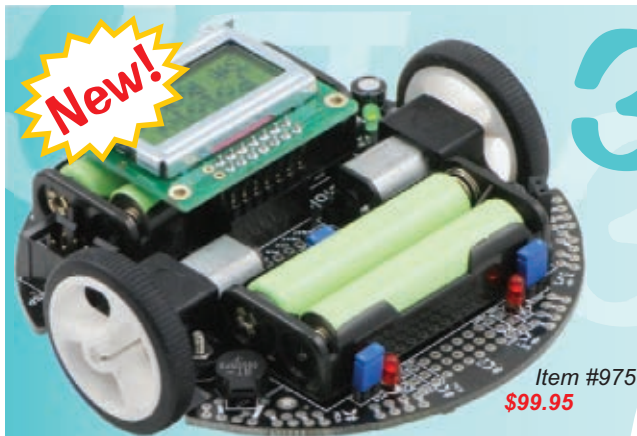
```
//*****
//*          CHECK FOR CHARACTER IN RECEIVE BUFFER
//*****
```

```
char CharInQueue(void)
{
    return(EUSART_RxHead != EUSART_RxTail);
}
```

If we are ready to process the received characters we have found in the PIC's receive buffer, we extract them from the buffer one at a time using this function:

```
//*****
//*          RETRIEVE A CHAR FROM THE RECEIVE BUFFER
//*****
char recvchar(void)
{
    char tmpptail;
    // wait for incoming usart_data
    while ( EUSART_RxHead == EUSART_RxTail );
    // calculate buffer index
    tmpptail = (EUSART_RxTail +1) &
EUSART_RX_BUFFER_MASK;
    //store new index
    EUSART_RxTail = tmpptail;
    //return usart_data
    return EUSART_RxBuf[tmpptail];
}
```

Since everything the PIC will do depends on what it sends and receives to the VNC1L's command monitor, the rest of the coding will entail sending commands, handling command responses, and handling VNC1L events. For instance, the VNC1L will inform the PIC when the thumb



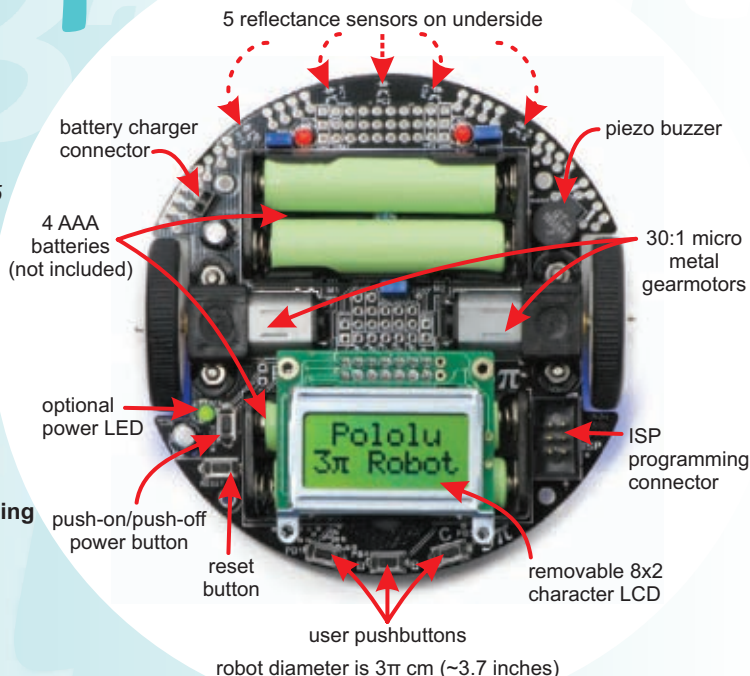
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drive is present and when the thumb drive is removed. We'll need to code for those events. We'll also need to code some file handling routines to open, close, read, and write files on the thumb drive.

## THE PLAN

As you can see, we still have lots of work to do before we can relish in the success of adding host USB functionality to a PIC. I also would like to exercise the VNC1L's I/O lines as they are an extension of the PIC's I/O subsystem. So, that means I'll be sharing some code with you to push and pull bits on the VNC1L's I/O pins. My plan is to plant a VDIP2 and a PIC on a breadboard and work out their "differences." Once I have a stable hardware design that works flawlessly with the firmware design, I'll transfer the hardware design from breadboard to printed circuit board. If all goes as planned, our next discussion will revolve around reading and writing thumb drive files and taking advantage of the rest of the VNC1L's USB host capabilities. I like to write code that is easy to follow and portable to other compilers and languages. So, I'll write the code using the HI-TECH PIC-18 PROC compiler. I also don't like to rope you into a particular PIC if the application doesn't demand it. I'll use the PIC18LF2620 in my design. However, you can use any PIC microcontroller that supports an integral UART or EUSART that is backed up by an interrupt subsystem.

Next time, I'll provide a complete set of microcontroller API functions and hardware design details that will enable you to put a VNC1L and USB into your Design Cycle. **NV**

■ Fred Eady can be contacted via email at [fred@edtp.com](mailto:fred@edtp.com)

## SOURCES

FTDI — [www.vinculum.com](http://www.vinculum.com)  
VNC1L; VDIP2; Vinculum Firmware

HI-TECH Software —  
[www.htsoft.com](http://www.htsoft.com)  
HI-TECH PIC-18 PRO

Microchip — [www.microchip.com](http://www.microchip.com)  
PIC18LF2620



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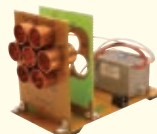


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**MK142 SMT LED Tree Kit \$10.95**

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**MK141 SMT LED Smiley Kit \$9.95**

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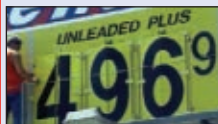
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# Q&A

## WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

✓ **Blinking Lamp Schematic**

✓ **Solenoid Driver**

✓ **Stereo Amp**

### ■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:

[Q&A@nutsvolts.com](mailto:Q&A@nutsvolts.com)

## 60 VOLT, 13 AMP SUPPLY

**Q** I need a power supply that puts out (max.) 60V at 13 amps. Ripple is not too important, as long as it is no more than 0.5V or 1V. I don't want to use expensive transformers, though. Is there a switching mode that can run off house current?

— Craig Kendrick Sellen

**A** Both these requests are similar enough to use the same basic circuit. The power output at 20 volts, 40 amps is 800 watts and the power at 60 volts, 13 amps is 780 watts. The power input will be higher due to losses, so plan on 1,000 watts input (8.3 amps at 120 VAC). Since the big deal for me is the transformer design, I will do that first. I am using the Magnetics, Inc., manual for ferrite cores. For high power, E core is recommended and a formula is provided for estimating the size:

$$WaAc = (P_o * C * 10^8) / 4eBfK \text{ where}$$

$P_o$  = Power output

$C$  = Current capacity in sq. cm per amp (.00507 for square waves)

$e$  = Transformer efficiency (90% or 80% for an inverter)

$B$  = Flux density in gauss

$f$  = Frequency in Hz

$K$  = Winding factor (0.3 for

primary side; 0.2 for toroids)

Using a flux density of 1,000 and frequency of 100 kHz, I get  $WaAc = 4.23$ . Checking the catalog, I find core 45021-EC has  $WaAc = 4$ ; that is close enough because my calculation was conservative. Checking the back inside cover, I see that this core is a standard; available in R material (if it is not a standard, then a minimum order is required). The catalog gives the bobbin window area = 1.78 sq cm = 0.276 sq in. Now see if the windings will fit: The mH/1000 turns (Al) for the core is given = 4600.

I want the no load primary current to be low compared to the full load current of 8.3 amps, so try 0.4 amps. The rectified line voltage will be  $120 * 1.41 = 170$  VDC, so the inductive reactance of the primary should be:  $Xl = 170 / 0.4 = 423$  ohms. The inductance at 100 kHz is therefore =  $Xl / 2\pi f = 673$   $\mu$ H. Now, using the formula  $N = (L * 10^6 / Al)^{1/2}$ , I get less than one turn; use 15 turns so there is more than one turn on the secondary. The catalog gives this formula for the primary turns:  $N_p = V_p * 10^8 / 4BAf$ . I don't know what A is but if I use the minimum area given for the core,  $N_p = 170 * 10^8 / 4 / 1000 / 2.13 / 10^5 = 20$ , that is a good number; go with it and see if it fits.

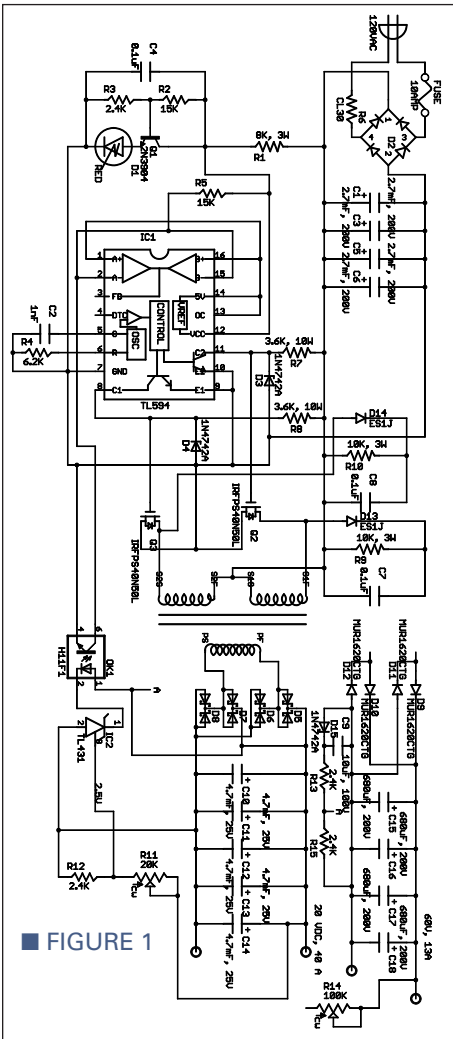
For the eight amp primary current, I think #16 wire will be okay, but winding #16 solid wire will be difficult. Use four parallel #22 wires for a total of 80 primary turns. Each

wire is .02535 inches in diameter. If I square that times 80 turns, the primary wire area is .051 sq in.

For the 40 amp secondary, the number of turns is:  $20V * 20T / 170V = 2.4$ . Can't have partial turns, so use three turns and that might be enough to compensate for losses. For 40 amps, you should use #10 wire but that would be impossible to bend around the small bobbin. Use 16 #22 wires in parallel for a total of 48 turns. The secondary wire area in this case is .031 sq in. Adding the primary and secondary, the total is .082 sq in and will easily fit in the available 0.276 window.

For the 13 amp secondary, the number of turns is:  $60V * 20T / 170V = 7.06$ . Use nine turns to allow for losses and regulation. For 13 amps, you should use #14 wire but again, that is too difficult to bend. Use eight #22 wires in parallel. With 72 turns #22 wire, the area requirement is:  $.02535 * .02535 * 72 = .046$  sq in. This plus the primary will also fit in the window.

You can wind the multiple wires individually and parallel them when you are done. If you wind them all together, only fasten them at the start end and parallel them when you are done winding. You will need to compute the length of wire needed and allow plenty of extra because it will take more than you think. I recommend using a compression splice to connect the parallel wires and convert to a single solid wire for



■ FIGURE 1

insertion in the printed circuit board (if you use a printed circuit board). Put insulating tape between the primary and secondary for safety.

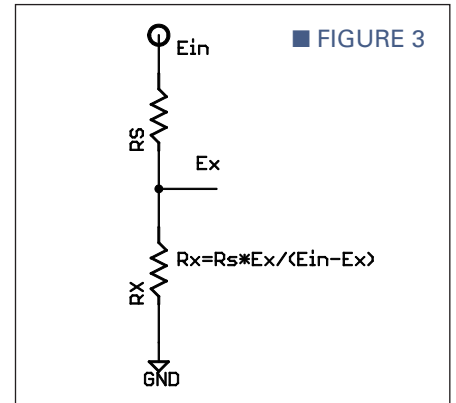
Now on to the circuit. I will use push-pull (see Figure 1) because otherwise there will be DC in the

primary which will require a larger core. That means doubling the primary turns and now the window is getting tight. I probably can't double the secondary in order to use the two diode, full-wave rectifier circuit and will have to use the four diode bridge rectifier.

The multiple filter caps are necessary to meet the ripple current requirements of the circuit and reduce the ESR (equivalent series resistance) of the filter. The TL594 is an old device but still good. It provides push-pull output with a dead time to allow one transistor to turn off before the other turns on. The oscillator runs at 200 kHz and is divided by 2 for 100 kHz drive to the transformer. The parts list is Figure 2.

## HOW TO MEASURE IMPEDANCE

Way back when (early '70s), I worked for a small electronics firm that did government work, sub and aircraft intercoms, and aircraft missile power supplies. I got the project of measuring and cataloging a pallet load of speakers, about 50 of various sizes and all unmarked. We had three engineers and one senior lab tech; all scratched their heads and walked away mumbling. After many phone calls, I got the answer. To measure the Z of the speakers, I used an audio signal generator and a VTVM. (Goes



■ FIGURE 3

ta show ya how long ago!) But for the life of me I can't remember the procedure to measure the speaker Z.

Any ideas on how the home hobbyist can do this?

— Bob J (long time subscriber)

When a resistor is placed in series with an inductor and the resistor is equal to the inductive reactance, the voltage across the inductor is 0.707 of the applied voltage. But the speaker has a large resistive component or else there is no sound. Since the speaker is resistive, the voltage divider in Figure 3 can be used. Rs is the known series resistance; Rx is the speaker impedance. The current through the speaker is:  $(V_{in}-V_{out})/R_s$  and the resistance  $R_x = V_{out}/I = (V_{out} * R_s)/(V_{in}-V_{out})$ .

## 8.4 VOLT REGULATOR

I recently acquired a Heathkit Utility Solid-State Voltmeter, Model IM-17 that requires two batteries. One is a 1.5V C cell and the other is 8.4V mercury; a little smaller around than a C cell and larger than an AA. I would like to replace the 8.4V with a 9V battery because they are cheap, easy to find, and will fit into the 8.4V battery holder. I need an 8.4V voltage regulator circuit to use with the 9V battery. I know I can use the 9V battery without a regulator but the result will be short battery life, excessive zero

## PWM SUPPLY PARTS LIST

■ FIGURE 2

PART	DESCRIPTION
R6	Inrush current limiter
D2	Bridge, 25A, 200V
C1, C3, C5, C6	2,700 µF, 200V electrolytic
C4	0.1 µF, 50V, 10% ceramic
C2	1,000 pF, 50V, NPO
C10, C11, C12, C13, C14	4,700 µF, 25V electrolytic
C15, C16, C17, C18	680 µF, 200V electrolytic
R1	8.2K, 3W, 5%
R2, R5	15K, 1/4W, 1%
R3	2.4K, 1/4W, 1%
R4	6.2K, 1/4W, 1%
R7, R8	3.6K, 10W, 5%
D3, D4	12V zener, 1W
D5, D6, D7, D8	Dual 30A, 45V, TO-220
Q1	2N3904, general-purpose NPN
D1	Red LED, T-1 3/4
Q2, Q3	NMOS, 500V, 40A
TRANSFORMER	See text

MOUSER P/N
527-CL30
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81-RPER71H104K2P1A03
81-RPE5C1H102J2P1A03
647-UHE1E472MHD
647-UPW2A681MHD
594-5093NW8K200J
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271-2.4K-RC
271-6.2K-RC
588-20J-3K5E
78-1N4742A-TAP
747-DSSK60-0045A
610-2N3904
859-LTL-4213
844-IRFPS40N50LPBF



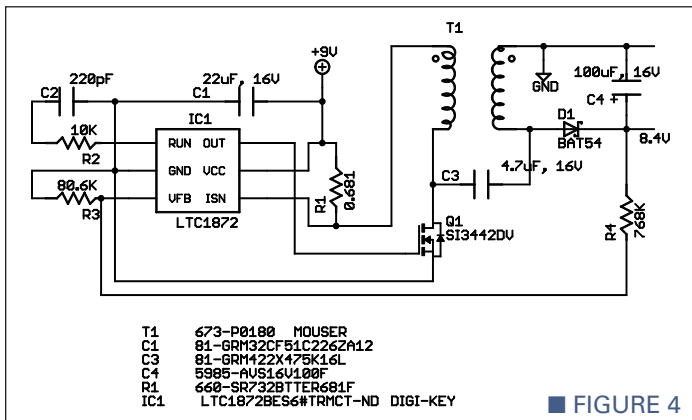


FIGURE 4

drift, and possible battery contact problems. Any ideas would be greatly appreciated.

— Dale P. Appleton

**A** The IM-17 draws less than 500 microamps from the battery, and the circuit is designed to be somewhat independent of the battery voltage. The regulator circuit will draw more current than the IM-17, so battery life will not be improved. I have in mind a SEPIC converter using the LTC1872B. The B version has burst mode inhibited allowing it to operate at low current output. Because of the low current output, the efficiency will not be better than 50%. The SEPIC circuit will work when the input is less than the output, possibly as low as three volts; the battery will crash however, when the voltage gets below about seven volts.

Figure 4 is adapted from the LTC1872B datasheet; I selected parts from the Mouser catalog, except for the LTC1872B which is available from Digi-Key. The LTC1872B is a current mode PWM regulator operating at 550 kHz. The threshold current sense between pin 4 (ISN) and pin 5 (VCC) is normally 400 millivolts. When the

energy in the primary inductance to the output and acts as a snubber for the drain of Q1. Note that when Q1 is turned on, the anode of D1 goes low. It is the stored energy of the magnetic field that is transferred to the output.

## BLINKING LAMP SCHEMATIC

**Q** I'm somewhat of a newcomer when it comes to electronics. I need a way to make a 12 volt, 500 milliamp lamp flash on and off repeatedly every couple of seconds, like blinking an eye.

— Gary D. Myers

**A** The schematic for the blinking lamp is in Figure 5. The output of the 555 timer is high, turning on switch Q1, while C1 is charging. When the voltage at pin 6 (threshold) reaches 2/3 of VCC, pin 7 (discharge) and pin 3 (out) go low. The output remains low while C1 discharges, until the voltage reaches 1/3 VCC. At that point, pin 7 goes open, allowing C1 to charge

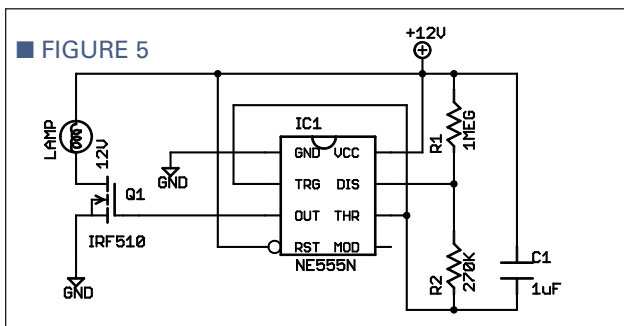


FIGURE 5

drop across R1 exceeds the threshold, the pulse to Q1 is cut off. The threshold is variable via the feedback to allow regulation. The capacitor, C3, has a dual function: It passes power from the stored

through R1 and R2; the output goes high, completing the cycle. Since the eye is open most of the time and closes only momentarily, I designed it for 0.9 seconds on and 0.2 seconds off. That is quite fast blinking, so you can increase the resistor values to make it slower. I suggest using a film or ceramic capacitor.

## PROGRAMMABLE CURRENT SOURCE

**Q** I want to design a programmable current source for checking the forward voltage of unknown LEDs. I plan on using a small microcontroller to display the current and voltage at the test points. What I want to do is vary the current output using a PWM signal from the micro. Many would say this is just a simple op-amp current source, but when you don't know analog electronics, nothing analog is simple! I want to vary the current from 0 to 100 mA in 1 mA steps and run the whole thing from a nine volt battery. Can you help?

— Tom Blough

**A** My solution to your problem is shown in Figure 6. The input PWM is divided by 5 via R1 and R2. Five volts DC input will require one volt feedback to the - input, which means there must be 100 mA flowing through R3 and the diode under test. You will have to calculate the diode drop ( $V_{tp}-V_{fb}$ ), but I don't see a simple solution to that problem. If you make the input pulse width 1/100 of the period, the average will

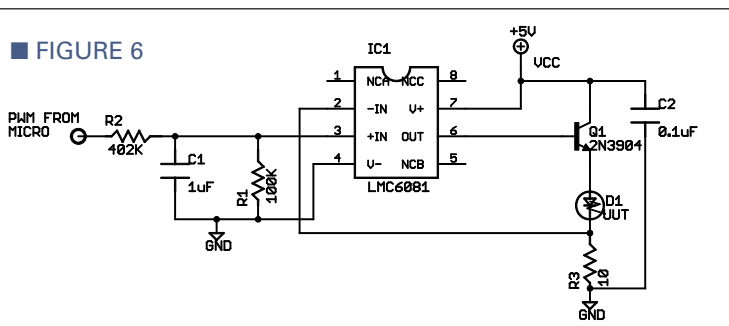


FIGURE 6

be 10 mV (5/5/100) and the current through the diode will be 1 mA. I designed the filter for a 100  $\mu$ s period; you could make C1 larger and use a longer period but you have to wait five time constants before taking the  $V_{tp}$  measurement. With 1  $\mu$ F, the time constant is:  $R1 \cdot C1 = 0.1 \text{ Meg} \cdot 1 \mu\text{F} = 0.1 \text{ second}$ . You must wait at least 0.5 seconds for good accuracy.

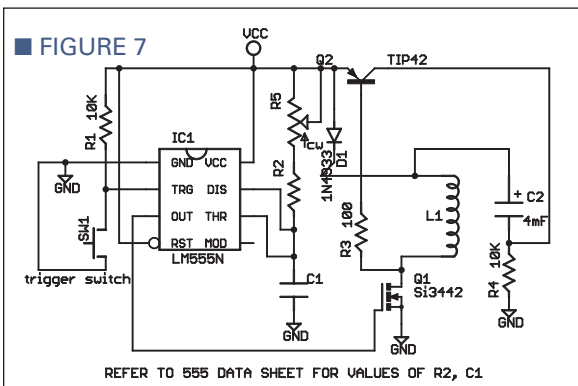
I was going to run it from the five volts of the micro supply, but realized that there is not enough head room to measure a blue LED, so that is why  $V_{CC} = \text{nine volts}$ . When measuring a red LED,  $V_{tp}$  is about three volts. That leaves six volts drop across Q1, and at 100 mA the power dissipation is 0.6 watts. That is a bit too much for a 2N3904, so I am recommending 2N2219. I don't think you will need a heatsink.

## SOLENOID DRIVER

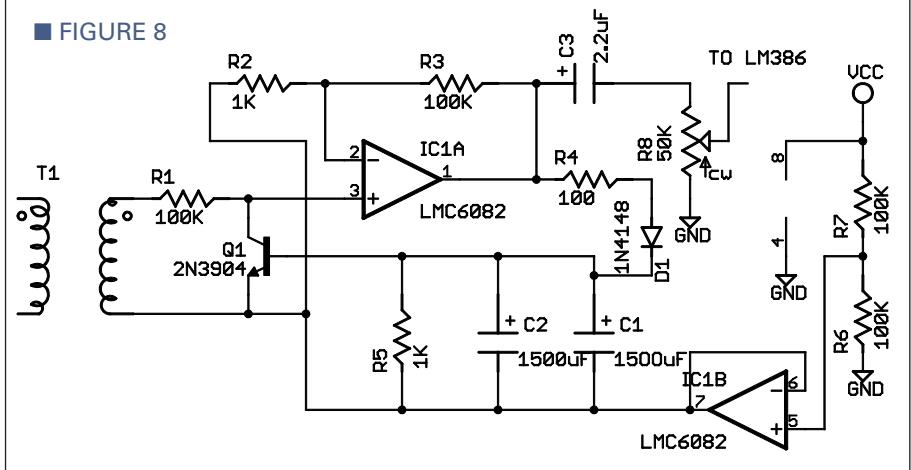
**Q** I need help making a circuit that activates a solenoid with a switch. The amount of time that it stays activated needs to be adjustable and it needs to activate as fast as possible. Can you help me?

— Dalton Jager

**A** This circuit (Figure 7) will work with input from 5 to 15 VDC. I had to make some assumptions about the solenoid: operating voltage is 12 VDC; current draw is one amp. Most mechanical relays will pull in 15 milliseconds, so I used that number for the time the solenoid



**FIGURE 8**



will have to pull in.

Assuming that the solenoid will stay pulled in down to eight volts input, then the capacitor to energize the solenoid should be:  $C = I \cdot dt/dV = 1 \text{ amp} \cdot 15 \text{ ms}/4\text{V} = 4000 \mu\text{F}$ . You can use this same formula if you have a different solenoid.

The way this works is: The 555 turns on Q1, which turns on Q2. Q2 pulls C1 up to double the voltage on the solenoid. When the charge on C1 is depleted, current flows through D1 to keep the solenoid pulled in as long as the 555 output stays high. I would use a fast diode for D1, like a 1N4936. For Q1, use Si3442DV or similar; for Q2 use TIP42.

## TELEPHONE LINE MONITOR AGC

**Q** I need an audio amplifier that will provide an equal level of output for both sides of a telephone conversation. I searched the web for a schematic or a kit that will provide automatic gain control in this kind of application, but could not find one. We currently use a 600:600 ohm audio transformer (in series with capacitors) bridged on the POTS line on the input side and an LM386 on the other side of the transformer. This allows monitoring (and/or

recording) of both sides of the conversation for quality control and order confirmation purposes. However, many times the caller can barely be heard while the agent's voice is extremely loud. Can you suggest a circuit that will output both sides of the conversation at the same level?

— Stan Grupinski

**A** In the circuit in Figure 8, the 2N3904 is acting as a variable resistor. It is very non-linear so it is necessary to keep the signal level small; in this case, about 10 millivolts. The amplifier gain is 101 so the output is about one volt p/p. R4 and the capacitors C1 and C2 are a low pass filter to provide some averaging and not respond to peaks. This slows the attack time but the attack time is about 200 ms, which should not be objectionable. R5 discharges the capacitors so that low level signals can be attenuated less. The decay time is about 300 ms. I assumed that you were using a single supply, so used IC1B to provide  $V_{CC}/2$  and prevent clipping of the signal. The circuit should work from 5 VDC to 12 VDC.

## PROTECTION DIODES

**Q** I have an H-bridge driving a motor at 310 VDC and 3.5 amps. The internal body diode of the FET is rated 535 ns recovery time. I think that is





why I am having blown high and low output transistors. I plan to put MUR160 fast diodes across the FET; my question is: Will one amp be sufficient when I am chopping at 20 kHz? The MUR160 diodes are rated 35 amps for 8.3 ms.

— Anonymous

**A** With a forward current of (maximum) 3.5 amps, the one amp diodes should work okay. But, if you had a 1  $\mu$ S delay between turning off one half bridge and turning on the other, the fast diodes would not be needed. Even with the fast diodes, there should be a 50 ns delay.

## STEREO AMP

**Q** I recently upgraded my old stereo to a five channel home entertainment system. Although the amp is rated at 100 watts per channel, it puts out about half that. I'd like to build a stereo amplifier that would take the output from the front two speakers of my five channel system and drive the 200 watt front speakers. Preferably one that could be switched in and out and one in a kit. Thanks.

— Ed Bixby

## MAILBAG

Dear Russell,

Re: Vibrator Replacement, September 2008, page 28.

Although it's possible to replace the 6X4 rectifier with a solid-state replacement, I would suggest that the B+ voltage reading be taken before and after the modification. Double-check that you're not exceeding the voltage rating of the filter capacitor.

Early electronic design had

generous (by today's practice) headroom in component selection values, but the leap from a 0.7 volt forward voltage drop device from a 20 volt forward drop per section device may push the original filter design pretty close to the maximum rating of the capacitor. Keep up the good work!

— John Mattesini

*Response: Thanks for the feedback, John. I had not thought of that problem.*

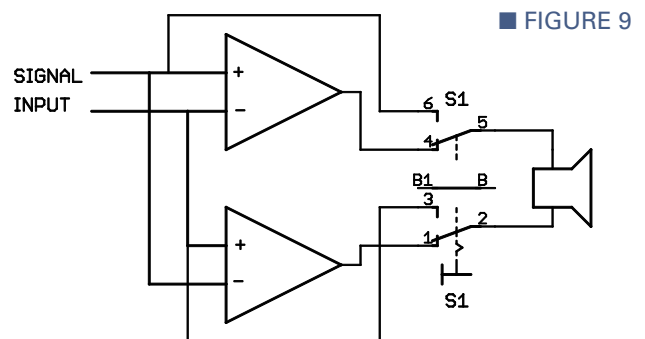
**A** QKits part number K4005B (<http://store.qKits.com>) looks like what you want. It is rated 2X100W into four ohms, but it can be bridged to provide 200 watts mono into eight ohms. You will need to buy two to have 2X200W. The price is \$159.95 which seems quite reasonable.

From the size (350 x 62 x 85 mm), I am sure it is PWM, not linear. A power supply kit is also available.

Figure 9 shows how the two inputs of the right and left channels are connected for bridging and how I would switch

the output to take the added amp out of the circuit.

The driving amp will be essentially no load when the 200 watt amp is in, and the 200 watt amp will be no load when it is not connected to the load. I don't think this will damage the amps, but you should check with the manufacturer to be sure. **NV**



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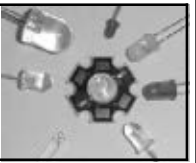
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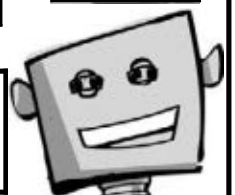


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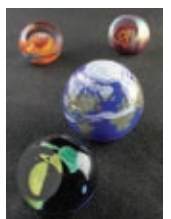
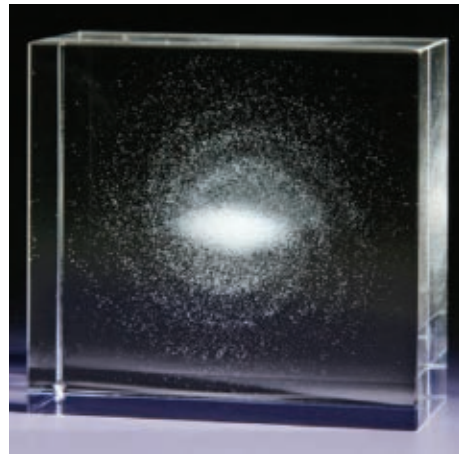
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# THE BIG EAR

BY JIM STEWART

**Ever wish you could build an “audio telescope” that would let you hear things that were faint or far away? Well, this article shows you how to build such a thing. We call it the Big Ear.**



**T**he Big Ear is shown in Figure 1. Its most obvious feature is its parabolic dish reflector. The reflector concentrates sound energy onto a microphone that connects to a very high gain amplifier (see sidebar on parabolic reflectors). And believe it or not, it's all assembled on a wood base you can find in a place that sells concrete supplies and tools! More about the wood base later; first we'll discuss the amplifier.

The amplifier is built on a printed circuit board (PCB) and mounted on stand-offs inside a small aluminum box along with a nine-volt battery. Jacks for the microphone and headphones — along with an on-off switch and a volume control — are mounted on the box. Input jack J1 accepts a 2.5 mm mono plug that is wired to an electret microphone. Output jack J2 is for a 3.5 mm stereo plug that is standard on many headphones.

## Circuit Description

Figure 2 is the amplifier schematic. Voltage to power

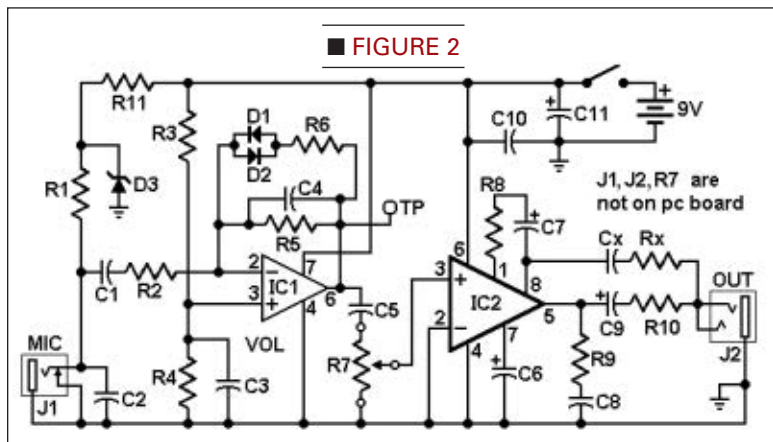
the microphone comes from the five-volt zener diode D3. Resistor R11 limits the current in D3. The five volts are applied through resistor R1 which sets the bias current for the mic and the gain of the FET amplifier built into the mic. Also, R1 and C2 form a low-pass filter to remove any high frequency electromagnetic interference (EMI) that might come in via the microphone wires.

The microphone is capacitively coupled via C1 to inverting amplifier IC1. Because of C1, DC gain of IC1 is 1 while the AC gain is set by the ratio  $R5/(R2 + R1)$ . C4 across R5 limits the bandwidth of IC1. With a wide-band amplifier like the TL071, you should limit the bandwidth to limit the noise (see sidebar on op-amp noise). For op-amp IC1, the inputs need to be referenced to a level that is between the positive and negative voltage “rails.” Since the circuit is powered by a single 9V battery, R3 and R4 create a signal ground for the plus-input of IC1. C3 is a bypass cap to connect AC signal ground to DC ground.

Since the mic will pick up loud sounds as well as faint ones, we need to limit the output of IC1. That job is done by R6 together with diodes D1 and D2. D1 and D2 are wired in parallel with opposite polarity to allow current to flow both ways. Normally, the output of IC1 is a lot less than the 600 mV or so needed to put a diode into conduction. So, the diode pair acts like an open circuit and R6 is isolated. A loud sound drives the output of IC1 high enough to turn on the diodes placing R6 in parallel with R5. That lowers the gain of IC1 from 5 down to about 0.1. D1, D2, and R6 form a limiter. Originally, I was going to use an automatic gain control (AGC) circuit, but it got too complicated. To keep things simple, I opted for a limiter. You can use an oscilloscope to see the output of IC1 at test-point TP.

Output of IC1 is coupled through C5 to the

■ FIGURE 2



volume control (R7). R7 has an *audio taper* instead of a linear taper. With a linear pot, the ohms per degree of rotation is constant. As a voltage divider, 20 degrees rotation gives twice the voltage of 10 degrees rotation. For most applications, that's what you want. But the way our hearing works, loudness increases with the *logarithm* of the sound power. An audio taper pot varies the resistance so that the change in loudness per degree of rotation is constant.

The wiper of R7 goes to the input of power amplifier IC2. Unlike IC1, IC2 has a built-in resistor network to establish signal ground for its inputs. C6 is a bypass cap for that internal bias network. Note that IC2 is used in non-inverting mode. Since IC2 is a power amp, it can draw relatively large current "slugs" from the battery which could cause small fluctuations in the nine-volt supply. Such fluctuations could be picked up at the input of IC1 causing an accidental feedback loop. If IC1 and IC2 were both inverting (or both non-inverting), it would be *positive* feedback and the whole circuit could oscillate. If one amplifier is inverting and one is non-inverting, it's *negative* feedback which is stable. There are other possible feedback paths through the supply. That's why we use

C11 across the battery and C10 from power to ground at IC2. Figure 3 shows the schematic of the LM386 used for IC2. For stability, the LM386 needs a 10Ω load at high frequencies, which is supplied by R9. C8 allows IC2 to "see" R9 only at higher frequencies. With pins 1 and 8 open, IC2 has a fixed gain of 20. To increase AC gain, a resistor (R8) in series with a capacitor (C7) is placed between pins 1 and 8. The AC gain is given by the formula:

$$A_V = 30K / R_{EQ}$$

where  $R_{EQ} = 150 + (R8 * 1.35K) / (R8 + 1.35K)$ . In this circuit, R8 is a jumper wire to get the maximum gain of 200. The DC gain stays at 20. The output of IC2 is coupled via C9 to the headphones jack J2. The 10Ω resistor in series with C9 does two things. First, it makes the output of IC2 look more like a current source for low impedance headphones. That can improve the sound quality. Second, it prevents IC2 from seeing a shorted output.

## Hiss Filter

The total gain of the amplifier circuit is approximately

## PARABOLIC REFLECTORS

Parabolic reflectors are everywhere, from radio telescopes to dish antennas for satellite TV to the reflector in a flashlight. Figure PR-1 is a photo of a parabolic reflector.

Parabolic reflectors like the one in figure PR-1 are based on the properties of a *parabola*, one of those *conic sections* you may remember from high school math. Figure PR-2 is the graph of a parabola showing *y* as a function of *x*.

The equation describing a parabola is  $y = x^2 / 4P$  where *P* is a constant, as shown on the graph. What's so special about a parabola? It's all about that point *P*, called the *focal point*. Imagine a bunch of ball bearings rolling across a table in straight lines parallel to the *y*-axis and hitting the inside of the parabola, which is lying on its side. All the ball bearings would bounce off the parabola and land at point *P* as shown in Figure PR-3. They are *reflected* to the focal point.

If we rotate the parabola around the *y*-axis, we get a three-dimensional figure: a

parabolic dish. (New technology? No; the properties of a parabola have presumably been known since the time of Euclid.) Parabolic reflectors are characterized by their focal length: the shorter the focal length, the deeper the dish. In terms of the graph in Figure PR-2, the focal length is how high up the *y*-axis the point *P* is located.

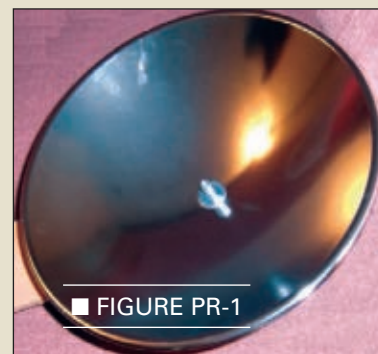
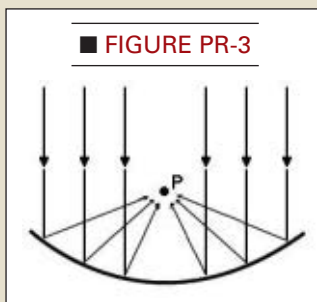
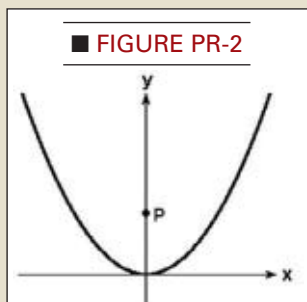
Instead of ball bearings, energy in the form of waves can also be concentrated at a focal point using a parabolic reflector. The size of the reflector depends on the wavelength of the waves you're trying to focus. Wavelength is how far a wave travels during one cycle of the wave, and is represented by the Greek letter lambda ( $\lambda$ ). We define wavelength as:

$$\lambda = s / f$$

where *s* is the speed of propagation and *f* is the frequency of the wave.

For best reflection, the diameter of the dish should be much bigger than  $\lambda$ . With RF microwaves, the wavelength is a few centimeters. With light, the wavelength is in nanometers. But with sound, the wavelength at 1000 Hz is about 34 centimeters (one foot). Because human detectable sounds can have frequencies from 100 Hz to 20,000 Hz, the wavelength can be equal to the diameter of the reflector at some frequency. Also, since sound is a *longitudinal* wave, the wavelength can interact with the focal length to cause cancellation at a specific frequency.

A large, deep dish reflector would be best for sound waves. But a 10 foot dish would not be hand-held, so some trade-off has to be made between the size of the dish and its ability to focus sounds.





## NOISE IN OP-AMPS

Basically, electronic noise is a bunch of sinewaves with random frequencies and amplitudes. All electronic components generate noise; even wires. Some noise is due to the random vibration of atoms due

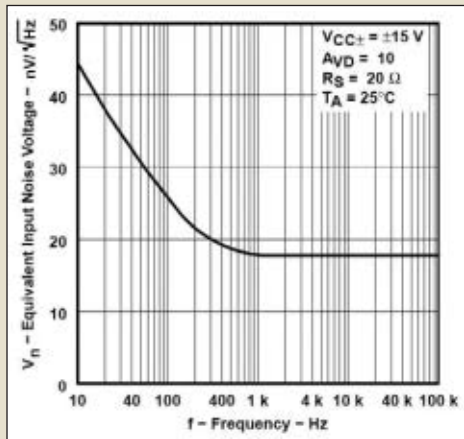
to temperature. Some noise is generated as electrons move through semiconductors. In all cases, the noise energy is distributed over a range of frequencies. Note that it's noise *power* that's important. A distinction is made between *noise* and *interference*. Noise is due to random physical processes while interference is man-made.

Noise in an op-amp is specified on its datasheet in units of  $nV/\sqrt{Hz}$  referenced to the input, meaning you multiply it by the gain of the circuit to find the noise on the output. Why does it include Hertz? Because the noise is spread over a range of frequencies. Why is there a square-root involved? Because power is proportional to  $V^2$  ( $P = V^2/R$ ). If you take  $V/\sqrt{Hz}$  and square it you get a number that is essentially power per Hertz. Then if you multiply that number by the bandwidth of the amplifier you get the noise power.

The TL071 data-sheet specifies  $18 nV/\sqrt{Hz}$  of noise. But look at Figure NSB-1. From about 500 Hertz and up, noise is  $18 nV/\sqrt{Hz}$ . But as frequency drops *below* 500 Hertz, the noise spec increases. We are seeing something called (for obvious reasons)  $1/f$  noise. In semiconductors,  $1/f$  noise seems to be due to the way electrons interact with randomly distributed impurities in the silicon. It's interesting to note that  $1/f$  type noise occurs in random processes of many physical systems besides electronic devices; for example, brain waves.

How significant is  $1/f$  noise? It depends on the bandwidth you're using. The frequency below which  $1/f$  noise starts to increase is called the *noise corner frequency* ( $f_{NC}$ ). If your application is at frequencies around  $f_{NC}$ , then  $1/f$  noise is important. If your application is at frequencies that are mostly above  $f_{NC}$ , then it isn't so important.

FIGURE NSB-1



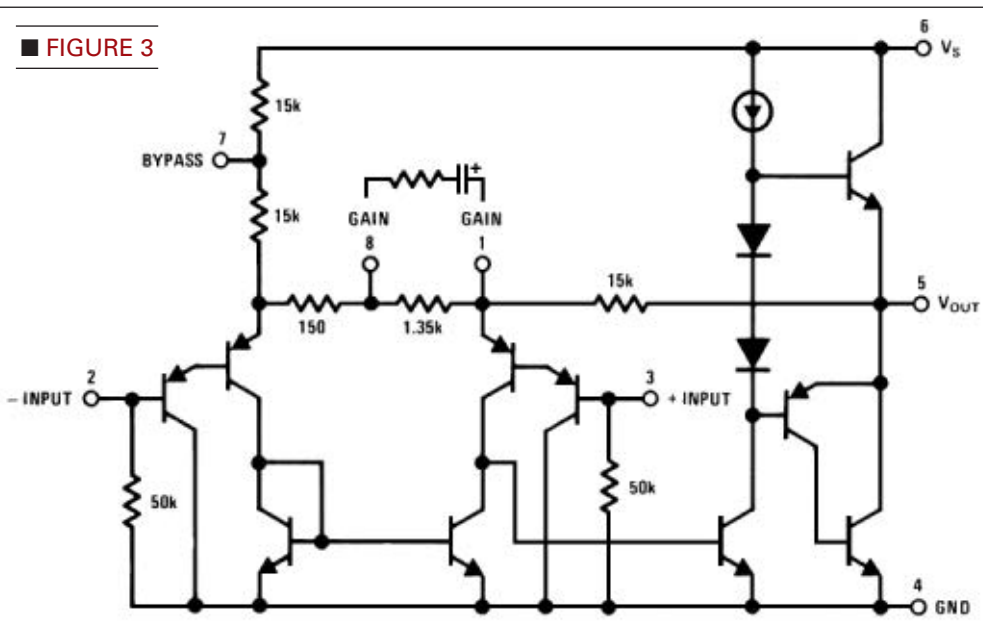
$5 \times 200 = 1,000$ . Even though IC1 is a relatively low noise op-amp, with that much gain you will hear some random noise in the form of a hiss. To lessen the hiss, you can install Rx and Cx to lower the gain of IC2 at higher audio frequencies. On the other hand, if you need to hear those frequencies (for, say, bird-watching), you can just leave Rx and Cx out. Or, you could mount another toggle switch on the aluminum enclosure and switch Rx in or out as needed. Rx shunts the internal 15K feedback resistor of the LM386. The LM386 is stable only for gains greater than 9, so if Rx is too small, IC2 could oscillate; the

datasheet suggests a minimum of 2K ohms.

## The Circuit Board

Parts are mounted on the PCB as shown in Figure 4. Figure 5 shows the assembled board. Note the three-wire connector between the volume control and the board. Since R7 is an audio taper pot, it must be connected so that turning its shaft clockwise increases the volume. The wires connecting the input jack to the amplifier should be twisted and kept away from other components.

FIGURE 3



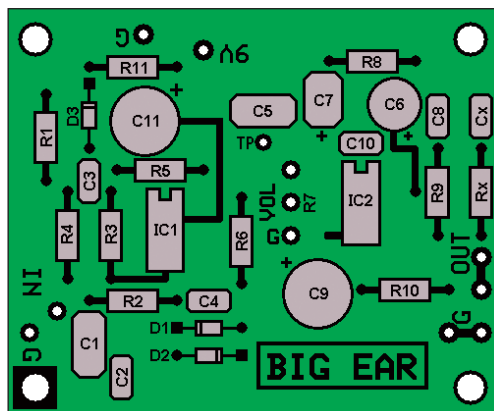
## Mounting the Amplifier in the Aluminum Box

Figure 6 is a photo of the aluminum enclosure. It's Radio Shack part number 270-238, with dimensions of  $5.25 \times 3.0 \times 2.13$  inches. In Figure 7, the enclosure is opened up to show the mounting of the amplifier PCB and battery holder along with the jacks, switch, and volume control.

The amplifier is mounted on four male-female 4-40 by  $1/4$  inch aluminum standoffs. One way to locate the screw holes for the standoffs is to use the blank PCB as a template.

Position the board where it will be mounted and — while holding it firmly in place — mark the hole locations by inserting the tip of a pencil into each hole and tracing its circumference. Lift off the board and press a sharp metal point into the center of each of the four circles you just drew. Then, drill the holes with an 1/8" drill bit. You'll also need to drill holes for the jacks, the volume control, the on/off switch, and the battery holder. For the jacks, find a drill bit that is slightly larger than the threaded part that goes through the sheet metal. If you use a pot with any anti-rotation tab, first drill the main hole for the pot. Then, insert the pot and rotate it so that the tab scribes a circle around the mounting hole. Drill the tab hole at some point on that scribed circle.

■ FIGURE 4



The metal battery holder is mounted to the box using four 2-56 pan head screws. I used small screws to avoid having the screw heads cut into the battery. Before inserting a battery, double-check the wiring from the battery holder to the PCB. You really don't want to apply reverse polarity to those chips.

## Testing the Amplifier

Before applying power, clean the board with rubbing alcohol and an old toothbrush, and give it a careful visual inspection. Look for the usual suspects:

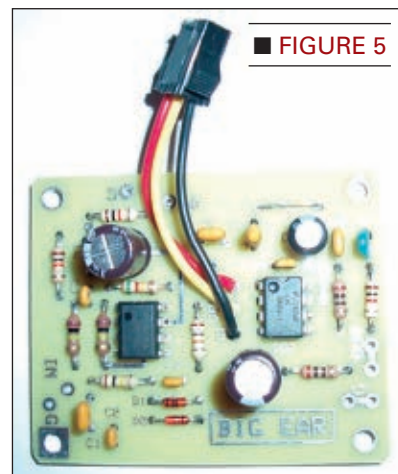
- Bad solder joints
- Broken copper traces
- Shorted copper traces (especially IC pads)
- Reversed polarity on capacitors
- Wrong value capacitor
- Diodes in backwards
- ICs in backwards
- Wrong IC in a socket (if you used sockets)
- IC (or socket) lead bent under and not in hole
- Missing components (especially monolithic caps)

Once you're sure there are no obvious problems, measure the resistance from +V to ground. If it's low or zero, there's a problem. If you used sockets, pull the chips out one at a time. If the short goes away, you've located the problem area. Otherwise, look for shorted traces.

Test the amplifier before mounting the box to the wood base. Insert a 9V battery and button up the enclosure. You'll need a 20 inch length of twisted-pair stranded wire. Each wire should have a different color. Jameco sells a 100 foot roll



■ FIGURE 6



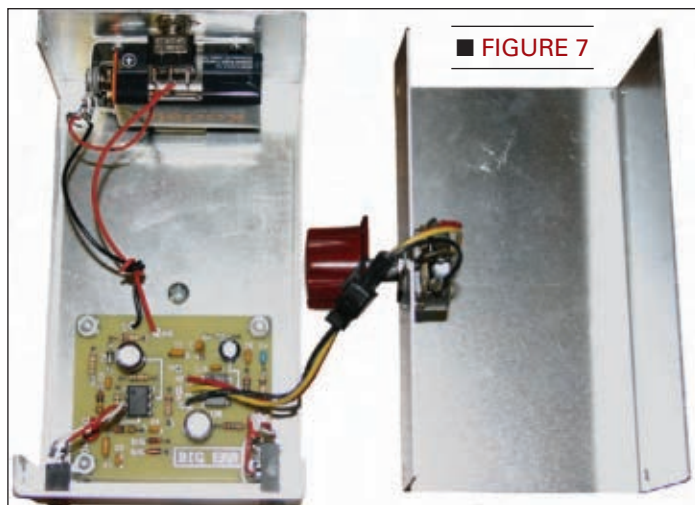
■ FIGURE 5

of BLK/WHT 24/2 wire as their part number 173164. You can also take two lengths of wire and twist them yourself. (I've seen people use a low speed hand-drill to do the twisting.) Attach the 2.5 mm plug to one end of the cable, and remember which color is signal (the tip) and which color is ground. Then, solder the electret mic to the other end. (Remember, electret mics are polarized; solder the ground wire to the pin that connects to the metal case of the mic.)

Plug in the headphones, plug in the mic, turn the amplifier on, and listen. Verify that the volume control works. If it all works, turn it off and unplug the mic and headphones. Unsolder the mic and proceed to mount the amplifier box to the wood base.

## Mounting the Enclosure to the Wood Base

Figure 8 is a photo of the wood base. It's a tool called a "float" and is used to smooth out freshly poured concrete. It's 15 inches long by 3.5 inches wide by 0.4 inches thick. It's model 8029 sold by Lowes under the TASK FORCE brand as number 024530 (for under \$5). The handle is offset, so the aluminum enclosure fits nicely on the long end while the reflector mounts to the short end. The

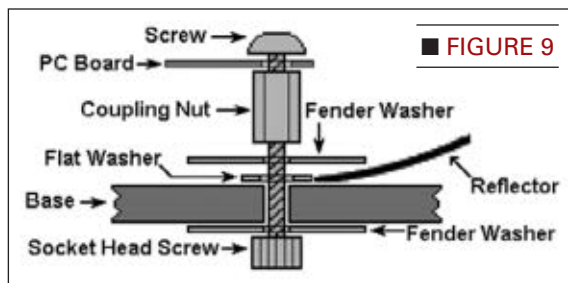


■ FIGURE 7





■ FIGURE 8



■ FIGURE 9

reflector has been attached in this photo.

Before you can mount the enclosure to the float, drill four holes in the wood to clear the heads of the 4-40 screws that hold the board standoffs to the box. That way, the enclosure will fit flush to

the wood as the screw heads fit into the holes. The holes don't have to go all the way through; 1/4 inch deep should do. Use a drill bit that is slightly wider than the screw head. Before drilling, hold the box against the base and push so that the four screw heads mark the wood. That tells you where to drill.

To attach the box to the base, hold the box flush to the wood and drill an 1/8 inch through the middle of the aluminum and through the wood. Then, put a wood screw through the hole and tighten it to hold the box to the wood.

## Mounting the Reflector to the Wood Base

The reflector used is an Edmund Scientific model 3053875. It has a 12 inch diameter, a three inch focal length, and a 0.75 inch center hole for mounting. To mount the dish to the base, drill a clearance hole for a 10-32 screw through the short end of the base. Use a carpenter's square and a pencil to draw a line across the

base just above the handle as shown in Figure 8. Then, draw two diagonal lines as shown. Where the diagonals cross is a point on the center line of the base. Use the carpenter's square to draw the center line through the point.

Position the reflector along the center line and mark the spot where you will drill the mounting

hole. Before mounting the dish to the base, we need to drill a 1/4 inch hole through the side of the dish for the microphone wires to pass through. Locate the hole close to the bottom of the dish, but not so close that it's blocked by the wood base. Insert a rubber grommet in the hole.

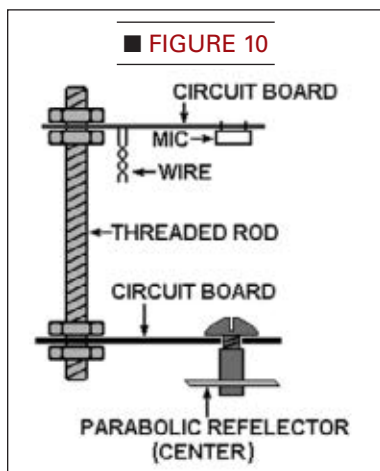
Figure 9 is a detailed drawing of the mounting hardware. (It is not to scale.) To keep it simple, lock washers are not shown. Note the 1/4 inch flat washer inside the mounting hole of the dish. Its outer diameter is about 0.74 inches; its purpose is to help center the mounting screw. The fender washers are 3/16 x 1 inch. The one under the coupling nut is used to hold the dish to the base. A 3/4 inch 10-32 socket head screw is used. You need to get the screw very tight, and a hex key allows much more torque than a screwdriver. The coupling nut has a 3/4 inch height and a 5/16 hex size.

Figure 9 is just one way to do it. You may have a better way to mount the reflector to the base. If you use a different reflector than the one used here, you'll have to figure out a way to mount it.

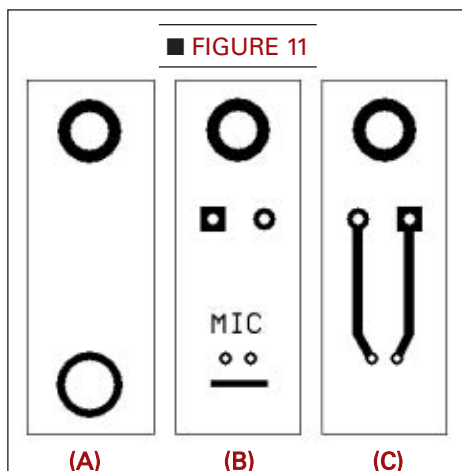
## Mounting the Microphone

For the reflector to work properly, the microphone must be mounted as close to the focal point as possible. The Big Ear uses two small PCBs and a length of threaded rod as shown in Figure 10 (again, not drawn to scale). The bottom PCB is mounted on the coupling nut at the bottom of the dish. The mic is soldered to the top board and faces towards the bottom. The top PCB has a clearance hole so it can be moved along the threaded rod

and be locked in place by two nuts and lock washers. Insert the twisted-pair wire through the grommet and wrap it loosely around the threaded rod a few times. Cut off any excess length and solder the wires to the top board. The square pad should be the mic ground, but verify that it is (see Figure 11). Figure 11 shows the PCBs used to mount the microphone. Figure 11(A) is the bottom board while 11(B) and 11(C) show both sides of the top board. The mic is mounted on the side with the word MIC on it. The mic is placed so that it lies over the strip of copper near the mounting holes. In Figure 11(A), note that the two holes are different sizes. The larger hole is



■ FIGURE 10



■ FIGURE 11

for a 10-32 screw that holds the board to the coupling nut at the center of the reflector. The smaller hole is for 6-32 threaded rod. Since the parabolic dish we used has a three inch focal distance, we used a three inch 6-32 screw instead of threaded rod.

## Adjusting Microphone Position

If you know the focal length of your dish, then use a ruler to position the mic at the focal point. If you don't know the focal length, there are two empirical ways to find it.

If your dish is shiny and reflects light, expose it to a bright light and use a piece of paper to find the focal point. Move the paper towards the bottom of the dish and find the point where the spot of light on the paper reaches its smallest diameter. That's the focal point. (If you use sun light, be careful not to burn a hole in the paper.)

If you can't use light, use sound. You'll need something that generates a steady audio tone at a frequency around 1 kHz. Point the dish towards the sound and adjust the position of the mic while you listen to the output of the amplifier. The sound will be loudest at the focal point.

## Headphones

Inexpensive headphones usually have ear pieces that sit on the ears letting some sound leak out. You can get feedback if the mic picks up the leaked sound. Better headphones have ear pieces that fit over the ears and don't leak sound. However, better headphones often use a 1/4 inch plug. You can get a 1/4 inch to 1/8 inch adapter at RadioShack (part number 274-875). Since 3.5 mm is slightly larger than 1/8 inch, the adapter will fit. Or, if you plan to use only those headphones, you can replace the 3.5 mm jack with a 1/4 inch jack.

## Wrap-up

Well, that's about it. Go out and discover all the neat sounds you've been missing with your new Big Ear. **NV**

**A complete kit for this project can be purchased from the Nuts & Volts Webstore @ [www.nutsvolts.com](http://www.nutsvolts.com) or call our order desk, 800 783-4624.**

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# BUILD A DOG DETECTOR

BY MICHAEL SIMPSON

We have several pets in our home, including two dogs. One of the problems we have is the dogs like to sneak into the kitchen and eat the cat's food. My wife asked me if there was any way we could create some sort of detector that would chirp each time a dog entered the kitchen. Of course, I said yes.

The key to this project is to detect only the dog and not a person or cat entering the kitchen. This can be done with two sensors at various heights and a bit of logic to decode the sensors.

I started doing some research and started looking into some of the various sensors available.

## Lasers and Photo Detectors

These would probably be the simplest to interface, but require two separate power sources and mounts: one for the lasers and the other for the photo detectors. This way also makes it difficult to relocate the sensor and adjust the heights of the sensors. There are also alignment issues. The small photo detector surface means you can only have a 1/8" variance. For these reasons, I decided these types of sensors are much too finicky for this application.

not well suited for this type of application. First, they are not very directional, and even by placing them in an enclosure they still suffer. Also, they tend to be sensitive to sudden changes in IR like a shadow moving across the sensor. After building and testing the Dog Detector based on these sensors, I knew I would have to look into another sensor.

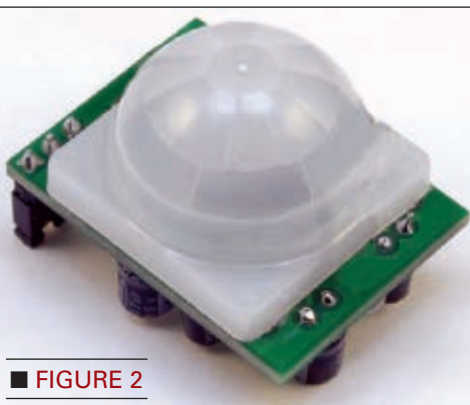
## Active IR Sensors

The concept behind active IR sensors is much like that of the PIR sensor. The main difference is that this sensor actually sends out IR energy and measures the amount of that energy reflected back. Many of these types of sensors modulate the IR energy to give them a certain amount of immunity from outside IR interference. Some of these sensors can actually return range information. The sensor shown in Figure 3 outputs a voltage based on the amount of IR energy that is reflected back. While these sensors are more immune to outside influences, they do have trouble when incandescent lamps are in use. They also have problems with various surfaces, as some do not reflect

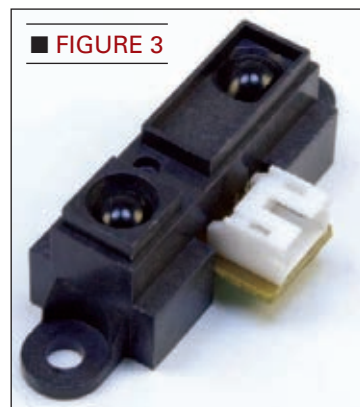
■ FIGURE 1

## Passive IR Sensors

These are also known as PIR sensors. This type of sensor monitors the amount of IR energy hitting the internal sensor and changes the state of the output lead when it detects a sudden change in this energy. The sensor shown in Figure 2 can be purchased from RadioShack for about \$10. I actually built the Dog Detector using these sensors but found that they are



■ FIGURE 2



■ FIGURE 3

the IR energy the same way. For instance, a black dog's hair will reflect very little energy back, while a white dog's hair will reflect much more.

After experimenting with this type of sensor, I again decided to look at other prospects.

## Sonar Sensor

I have used several sonar sensors in the past and have had good results with them. The problem is that the sensors have a very wide angle of detection. The folks at MaxBotix have come up with a line of ultrasonic range finders. They all use a single transducer so the size of these sensors is quite small. This single transducer configuration also helps keep the price down. You can review all the performance data for the complete line of sensors on their website at [www.maxbotix.com/Performance\\_Data.html](http://www.maxbotix.com/Performance_Data.html).

For this application, I found the EZ4 shown in Figure 4 is a perfect match (I've also used the EZ3 with great success). The EZ4 gives you the ability to shut it down using a control lead. This is important when using multiple sensors.

The EZ4 has four data interfaces, which makes it easy to measure its detected target distance. It will emit a pulse width proportional to distance, talk to you in 9600 baud serial (TTL inverted and requires decoding), generate an analog voltage (also proportional to distance) and finally, you can manually control the sensor element itself through the "ping" interface. We will use the analog interface in this project as it's my favorite.

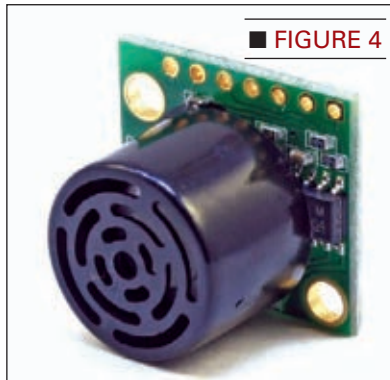
## Perseus Microcontroller

To monitor the two sensors, I will be using a Perseus microcontroller and Perseus Carrier 1. Shown in Figure 5, this is a very small and inexpensive controller. To program the controller, all that is needed is a \$10 EZRS232 driver and free software.

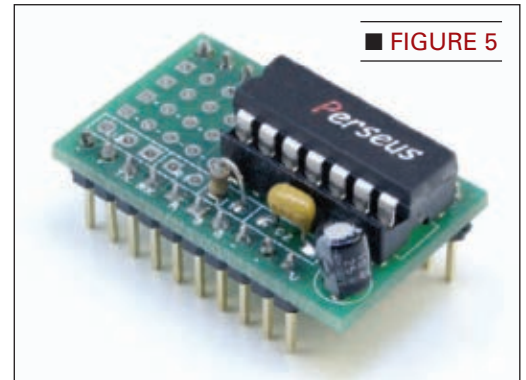
The carrier board (also shown in Figure 5) has a tiny prototyping feature that will allow for easy hookup of our sensors. This carrier also has the ability to add a 7805 voltage regulator to make powering our project very easy.

## Perseus Construction

I am going to take you step-by-step through the construction process. I will start with the microcontroller, then show you how to build the main stand for the project. Schematic 1 shows the completed hookup so that you can troubleshoot in case you have problems.



■ FIGURE 4



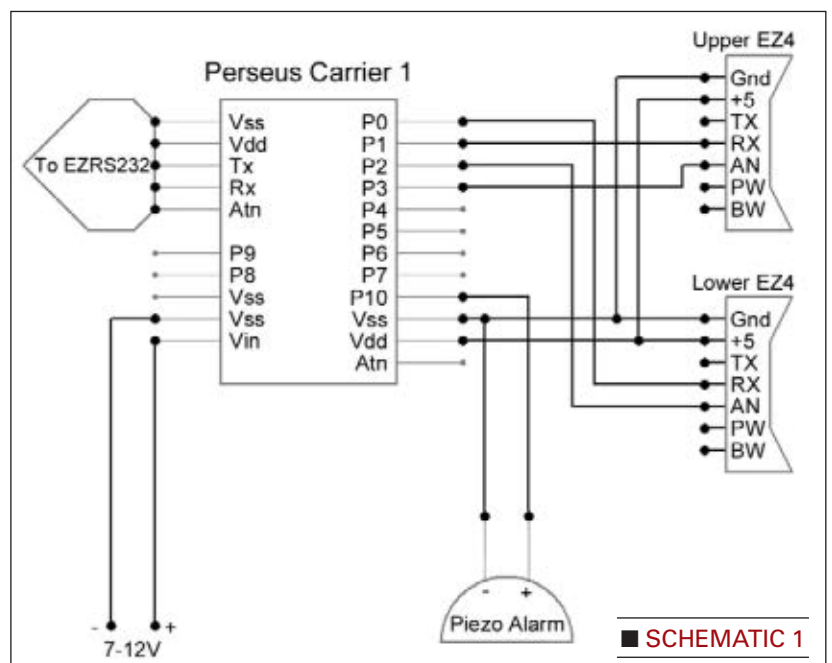
■ FIGURE 5

### • STEP 1

The Perseus Carrier 1 kit you need to build for this project comes with complete instructions. It is available from Kronos Robotics. Make sure you don't install the two headers, though. When complete, it should look like the carrier shown in Figure 6. The cost of the Perseus Carrier 1 is only \$6. If you want to experiment using a breadboard, I recommend that you purchase two carriers so that you will have one to play with outside the project. You can simply plug the Perseus into whichever carrier you are working on.

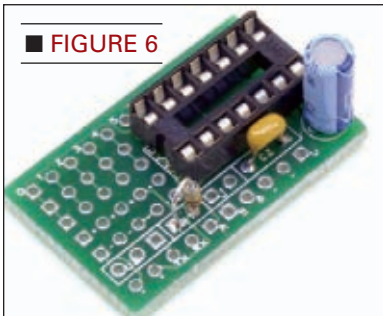
### • STEP 2

You will need to purchase a 7805 regulator and a couple of headers for the carrier. (This is also available for purchase as Option 1.) Attach a two-pin header to the carrier as shown in Figure 7. This allows you to jumper the regulator. Since we will always be using the regulator on this project, you can simply solder a wire in place of this header. If you do use the header, you will need to place a jumper across the two pins.

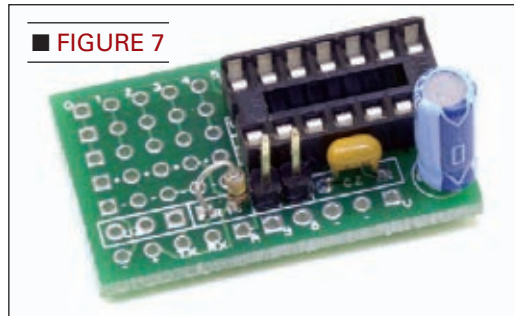


■ SCHEMATIC 1

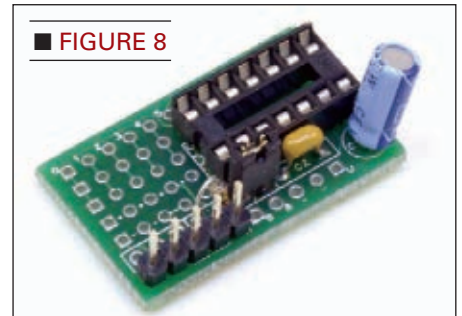




■ FIGURE 6



■ FIGURE 7



■ FIGURE 8

• STEP 3

Take a five-pin header and connect it to the carrier as shown in Figure 8. You can break this off from one of the unused headers. This header will be used to program the Perseus at a later time.

• STEP 4

Take a coax connector and solder a two-pin header to the connector as shown in Figure 9. Bend the connector pins closer together to hold the header in place while you solder it. The header does not have to be perfectly straight, but, make sure you have a good solder connection.

• STEP 5

Now attach the connector/header assembly to the carrier as shown in Figure 10. Pay careful attention to the pins and orientation of the connector.

• STEP 6

Once you solder the header in place, bend it as shown in Figure 11. This bend allows you to plug the AC adapter cord into the board at the same time the

EZRS232 adapter is being used.

• STEP 7

Attach a three-pin header to the carrier as shown in Figure 12. This step is optional. This header may be used later to add a servo for some sort of active reinforcement.

• STEP 8

Attach a 7805 voltage regulator as shown in Figure 13. I recommend inserting the 7805 just enough to solder the leads in place.

• STEP 9

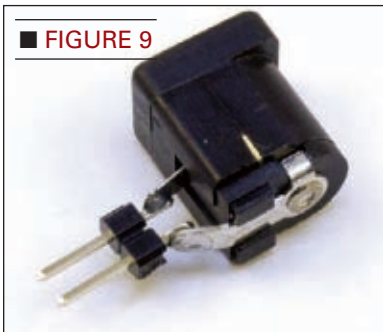
Attach a couple of wires to the piezo alarm as shown in Figure 14. I often purchase some multicolored 22 or 24 gauge ribbon cable for this type of hookup. All you need to do is peel off the number of leads needed. Each lead will have a different color, so it will be easy to keep track of the different connections.

• STEP 10

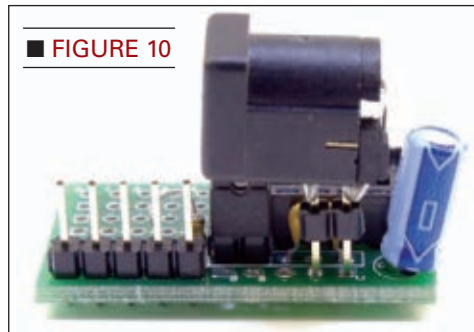
Attach the other end of the piezo cable to the carrier as shown in Figure 15. The + side of the alarm is connected to port 10 on the carrier. The other side is connected to the pin labeled Vss.

• STEP 11

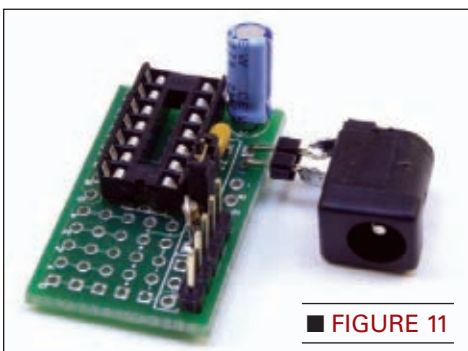
Drill two holes into a PVC cap as shown in Figure 16a. The center hole should be sized so that the piezo fits tightly into the hole as shown in Figure 16b. I drilled mine just a little smaller than the diameter of the piezo, then enlarged it with a file and knife. The hole near the



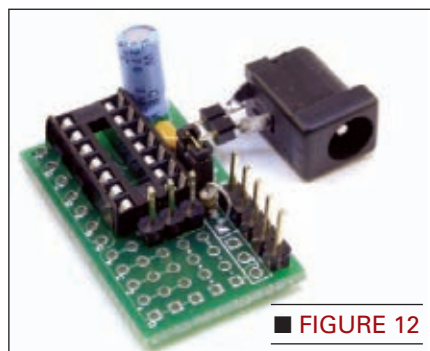
■ FIGURE 9



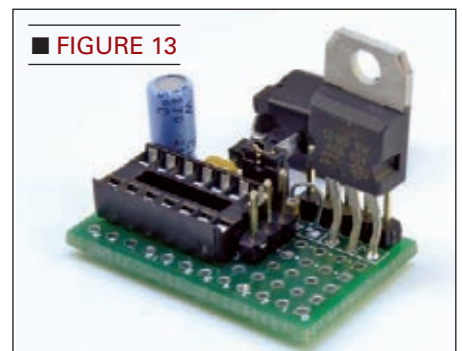
■ FIGURE 10



■ FIGURE 11



■ FIGURE 12



■ FIGURE 13

edge is used to insert the power connector on the AC adapter.

Once fitted, remove the piezo and set aside.

• **STEP 12**

First, we need to build the base. This will allow the detector to stand free. Cut a piece of 1-1/2" PVC pipe to about 2" as shown in Figure 17a. Take a 1-1/2" PVC cap and drill a 1/4" hole in the center as shown in Figure 17b. Next, drill a 1/4" hole in the center of a 1-1/2" PVC cross as shown in Figure 17c.

To assemble the base, run a 2-1/2" #6 machine screw down through the inside of the PVC cap, then the section of pipe, and finally through the hole in the PVC cross as shown in Figure 18. Place a nut on the end of the screw on the inside of the cross and tighten. As an option, you can drill a 1/2" hole on the other end of the cross and insert the machine screw through the bottom of the PVC cross. Then, go up through the small pipe section and into the cap. The goal here is to have the cap attached to the cross so that you can attach a 24" piece of tubing.

• **STEP 13**

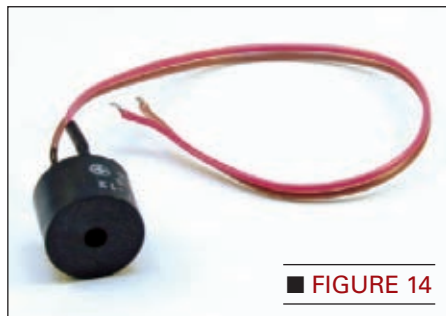
Peel off four leads of ribbon cable about 3' long as shown in Figure 19a. Strip each lead on both ends. Attach one end to the EZ4 sensor as shown in Figure 19b and Figure 19c. You will use the GND, +5, RX, and AN. The RX lead is used to disable the sensor when not in use.

• **STEP 14**

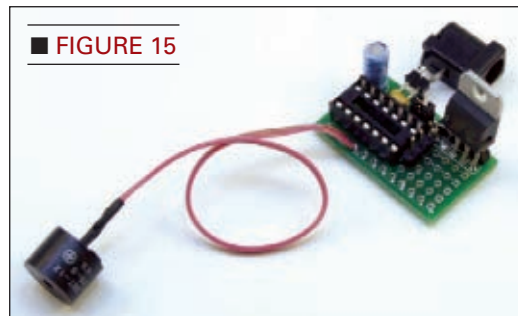
Take both of the 24" pieces of pipe and drill a 1/2" hole in each. The hole should be located at 18" from one end and 6" from the other as shown in Figure 20.

• **STEP 15**

Using some double stick foam tape, attach the EZ4 sensor module to the pipe, and run the cable through the hole as shown in Figure 21. As an option, you can use some small wood screws to attach the module to the



■ **FIGURE 14**



■ **FIGURE 15**



■ **FIGURE 16a**



■ **FIGURE 16b**

## STAND CONSTRUCTION

I built my stand out of 1-1/2" PVC pipe. It's inexpensive and can be painted. For this part of the project, you will need the following:

- Two pieces of 24" 1-1/2" pipe
- One piece of 2" 1-1/2" pipe
- Two 1-1/2" PVC caps
- One 1-1/2" PVC cross
- One 1-1/2" coupling
- One 2-1/2" machine screw and nut

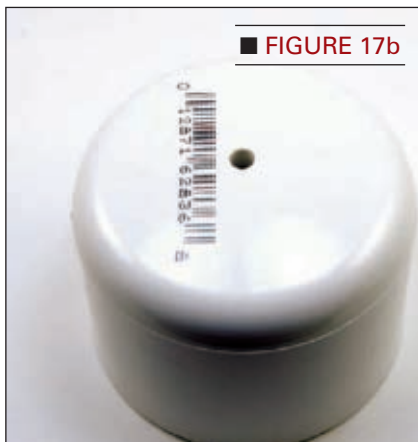
pipe. Just mark and drill some small pilot holes into the pipe first.

• **STEP 16**

Insert one of the pipes into the PVC cap on the base.



■ **FIGURE 17a**



■ **FIGURE 17b**



■ **FIGURE 17c**

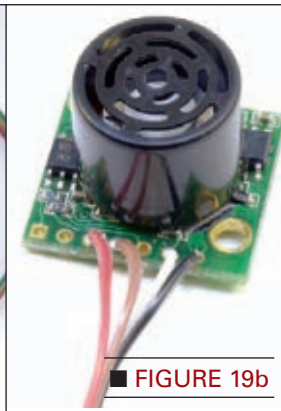




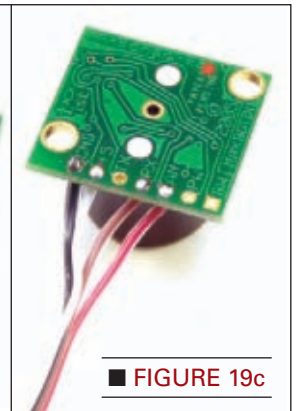
■ FIGURE 18



■ FIGURE 19a



■ FIGURE 19b



■ FIGURE 19c

Insert the pipe so that the sensor is near the top. Pull the cable through the top of the pipe and attach it to the Perseus carrier as shown in Figure 22.

Make the following connections:

- Sensor GND — Negative on port 0 bus of carrier (shown with the black wire.)
- Sensor 5V — Positive on port 0 bus of carrier (shown with the white wire.)
- Sensor RX — Port 0 on carrier (shown in gray.)
- Sensor AN — Port 2 on carrier (shown in blue.)

Please note that your colors will most likely be different than the ones I have here. I suggest you create a small chart on paper once you connect the ribbon cable to the sensor.

#### • STEP 17

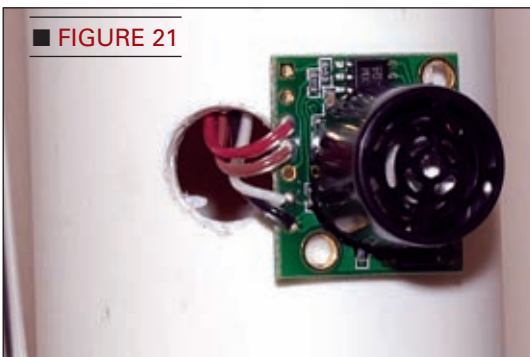
Attach a PVC coupling to the bottom of the other 24" pipe. This is the end farthest away from the sensor. Next, run the complete Perseus assembly up through the bottom of this pipe and out through the top. At this point, you should be able to attach the top pipe to the bottom pipe. Take the sensor wires from the upper sensor and attach them to the carrier as shown in Figure 23.

Make the following connections:

■ FIGURE 20



- Sensor GND — Negative on port 1 bus of carrier (shown with the black wire.)
- Sensor 5V — Positive on port 1 bus of carrier (shown with the white wire.)



■ FIGURE 21

- Sensor RX — Port 1 on carrier (shown in brown.)
- Sensor AN — Port 3 on carrier (shown in red.)

#### • STEP 18

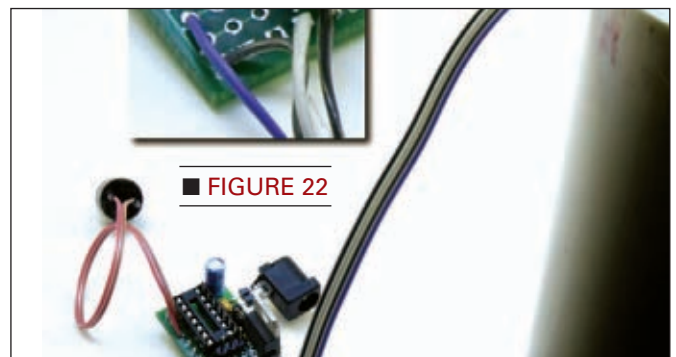
If you have not done so already, insert the Perseus chip into the socket on the carrier. The notch faces the center of the board. In order to program the Perseus, we need to connect the EZ232 driver to the carrier. The EZ232 and Perseus Carrier 1 are meant to be used on a breadboard. In order to program the Perseus in this application, you need to create a simple adapter by connecting two five-pin female headers together as shown in Figure 24.

To program the chip in our project, attach the EZ232 to the program header on the carrier as shown in Figure 25. Then, connect a 7-12V AC adapter (center positive) to the coax connector. At this point, you can connect the EZ232 to your PC with a nine-pin cable. Please note that there are a couple more options you can use to program the Perseus. You can build a second carrier and include the standard headers per the included documentation. With the second carrier, you can use a breadboard. You can also use an Athena Workboard Deluxe to program the Perseus.

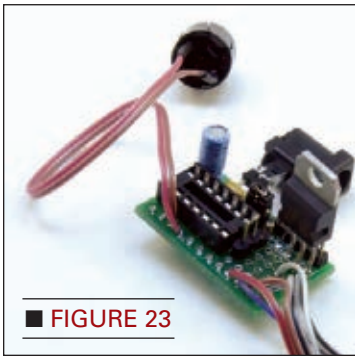
I have included a program called Doggy1.txt. The program will monitor the sensors and chirp the piezo when a dog is detected. Load this program into the Athena compiler and program the Perseus.

#### • STEP 19 (Final Step)

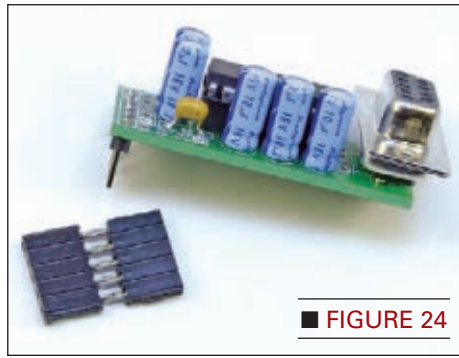
Remove the EZ232 and power connector from the



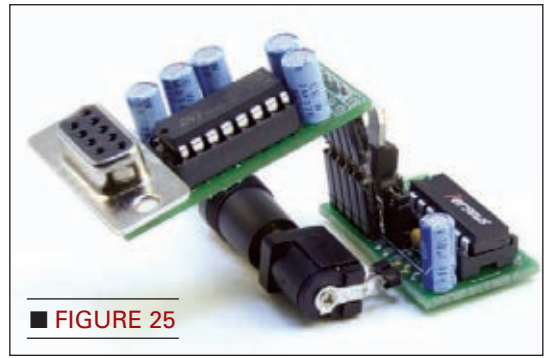
■ FIGURE 22



■ FIGURE 23



■ FIGURE 24



■ FIGURE 25

carrier and attach the piezo to the PVC cap as you did before. Next, run the AC adapter cable down through the other hole and then into the coax connector. You can now place the cap on the top of the Dog Detector.

## The Program

The Doggy1.txt program is straightforward. The first thing the program does after initializing the I/O ports is to take a set of calibration readings with the docal subroutine. This allows you to place the detector in many locations without having to change the code. The docal subroutine makes several calls to the sensor read routines then sets a couple of variables based on the last reading of each sensor. The value 10 is subtracted from this reading and will be used as the detection point for each sensor.

The Main Loop is where all the work gets done. An A-to-D (Analog-to-Digital) reading is taken every 10 milliseconds and compared against the calibration reading taken earlier. If the current reading is less than the calibration reading, the sensor is considered tripped.

Once tripped, a slight 50 millisecond pause is observed then 30 readings are taken from the upper sensor at 10 millisecond intervals. These readings again are compared against the calibration values and if triggered, it is assumed a human has passed the detector. If all 30 readings are taken without tripping the upper sensor, it is assumed that a dog has passed the detector and the chirp routine is called. After a pause of two seconds, the whole process starts again.

Normally, the RX lead of each sensor is held low to disable them from taking readings. When a reading from a sensor is needed, the RX lead is brought high, then after a 10 millisecond delay an A-to-D reading is taken from the sensors AN lead. After the reading, the RX lead is again taken low.

## NOTE

All the example programs, as well as the source code are available for download at [www.kronosrobotics.com/Projects/dogdetect.shtml](http://www.kronosrobotics.com/Projects/dogdetect.shtml).

## How Does it Work?

Unlike the early experiments using the IR sensors, the EZ4 sensors have proven a real winner. The small chirp from the piezo is just quiet enough not to annoy or wake you. It is enough to let both you and the dog know that he/she has entered where they should not have.

## Going Further

I added a three-pin header that would make it possible to add some sort of negative feedback to the detector.

The height of the lower sensor should be high enough to let small cats pass if you wish, and low enough to catch the dog. You could space the sensors to detect small children roaming where they should not be. **NV**

## PARTS LIST

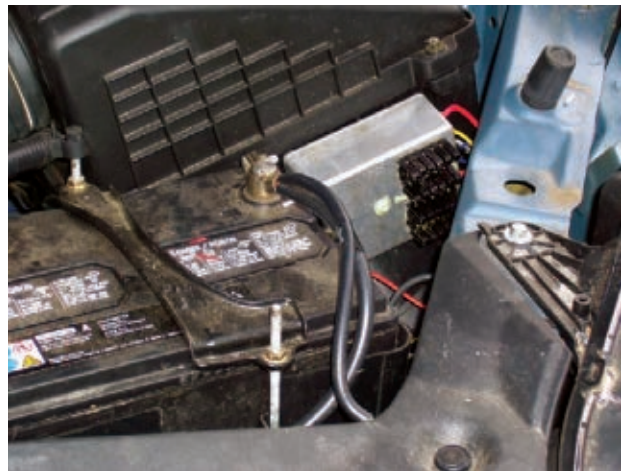
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# TWO ADD-ON GAUGES FOR THE AUTOMOTIVE ENTHUSIAST

BY ROBERT M. VOSS, W2HTN

**This article describes two add-on automotive devices. One of these is not found in production cars (to the best of my knowledge), but will be of interest to anyone who seriously wants to know what goes on under the hood. The second device seems to be standard equipment on more and more cars, and — in my home state of New York, at least — insurance companies will give a discount for its use. Both of these circuits can easily and safely be installed in any car without modification to the existing wiring.**



**T**oday's cars seem to have fewer gauges than those of a generation ago, relying more on idiot lights to alert drivers when something bad is about to happen. However, I believe there are still drivers who would like to know things like: how high or low their engine's oil pressure is, not just that it is about to seize; what is happening electrically, not just that the engine is about to die; and what is happening

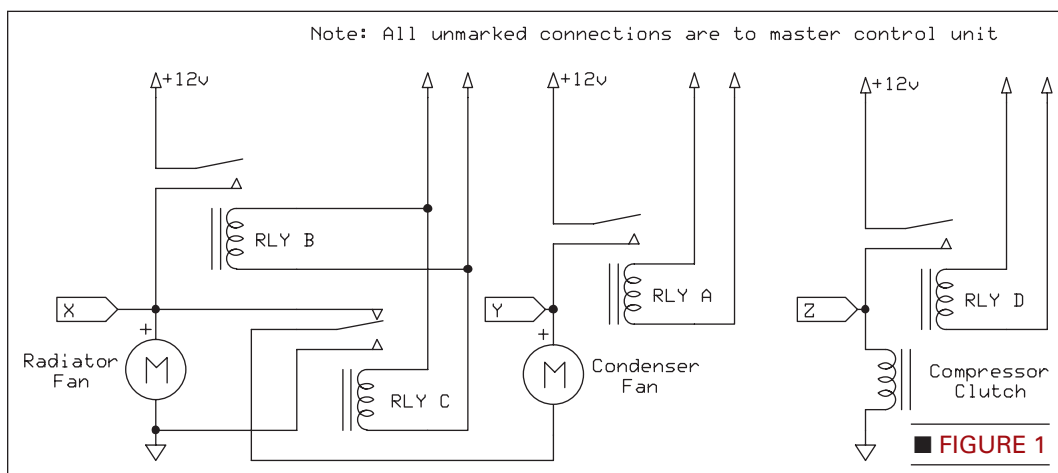
with the cooling system, not just that boil-over is imminent.

Figure 1 shows some of the electrical components of a typical 21st century cooling and air conditioning system. When the engine is started cold without air conditioning, relays A and D are open, so no power goes to either fan.

When air conditioning is required, and engine load — measured usually by vacuum — permits (relay D closes) and/or coolant

temperature increases, relay A closes, putting 12 volts (nominal) across the two fans in series. Assuming equal resistance in both (true in both of my cars), each receives six volts.

When cooling demands increase further, relays B and C close, feeding the full 12 volts to the fans in parallel. Knowing that the hot side of the radiator fan (point X) will measure either 0, 6, or 12 volts — depending upon cooling



■ **Note the LEDs are lit to show the compressor is on and the fan is at low speed.**



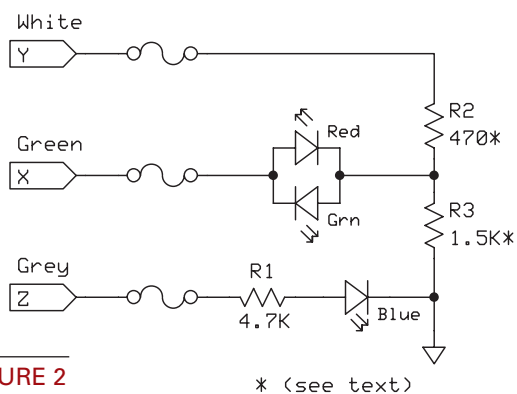
requirements — and that the hot sides of the condenser fan and compressor clutch (points Y and Z) will be at either 0 or 12 volts — depending upon cooling and air conditioning demands — allows us to monitor the electrical end of cooling and air conditioner operation.

The first device we'll build is a compressor/fan monitor. Its circuit is shown in Figure 2. I chose resistance values which would allow the LEDs (T1 3/4, in this application) to be visible in daylight but not distracting at night. For the same reason, I chose a blank panel fairly low on the dash for the display unit. When wiring, connect the fuses as close as possible to the relays and compressor clutch. Voltage divider R2 and R3 provide about nine volts at their junction when the fans are on, so the bi-color LED glows green when it receives six volts from the radiator fan (low speed) and red (12 volts) at high speed. The blue LED will be either on or off. If you hook everything up properly and get a compressor (blue) indicator light but no fan indication (red or green), stop and find out why.

I have installed this device in two cars and glance at them occasionally while driving to make sure things are as they should be. At high speed, the bi-color LEDs may faintly glow either red or green, depending upon the position of the fans in the engine compartment and their relative ability to act as generators. If the glow is very bright, that may indicate you need to slow down. In a smaller vehicle, you can use two T1 LEDs, double the values of the voltage divider resistors, and put a 15K resistor in series with the blue LED.

When I bought a 2006 model vehicle, I didn't check the specifications to see whether it came with daytime running lights (DRL) since I assumed this had become standard by that year. It turned out I was wrong. I ordered an add-on module from an auto parts catalog which failed after a couple of weeks of use. I decided to design and build my own. Figure 3 shows the second device: a DRL module. When the ignition is turned on, the low beam headlights are fed somewhat less than full voltage. This is typical, unless the car is not in gear (the automatic transmission switch grounds relay 2 in park or neutral) or the parking brake is on (relay 2 is grounded

Compressor/Fan Monitor for Honda



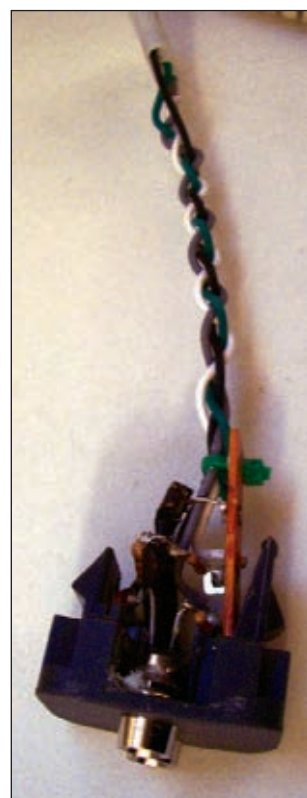
■ **FIGURE 2**

\* (see text)

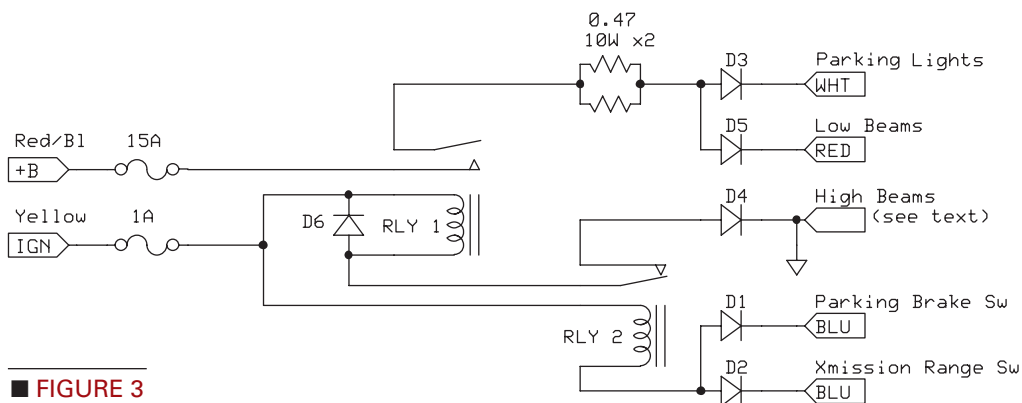
■ **The unused panel from the lower dash of my '06 Honda Odyssey; drilled to epoxy in two T1 3/4 LEDs. The wiring was braided and fed through the firewall to hook it up in the engine compartment.**

through the parking brake switch). My car has separate headlights for high and low beams, so turning them on together is not a problem. If you have dual-filament bulbs, then the black wire shown grounded should go to the high beam circuit instead so that you will not have daytime running lights and high beams simultaneously. D4 is necessary so that — should you flash the high beams with the ignition off (not possible in all cars) — the low beams won't also come on because of reverse activation of relay 1.

While I was building this



Daytime Running Light Control



■ **FIGURE 3**



## PARTS LIST

### DRL MODULE

- ☐ 15 amp fuse w/ holder assembly
- ☐ 1 amp fuse w/holder assembly
- ☐ RLY 1: 12 volt coil w/ SPST contacts capable of handling 20 amperes
- ☐ RLY 2: 12 volt coil w/ SPDT contacts capable of handling coil current only
- ☐ Resistors: 2 pieces: .47 ohm, 10 watt, with suitable heat sinking
- ☐ Diodes: D1, 2, 4, and 6: 1/2 amp, 50PIV  
D3: 8 amp, 50 PIV  
D5: 20 amp, 50 PIV
- ☐ Project box suitable to hold all parts and allow mounting in engine compartment space with good airflow

### MONITOR LIGHTS

For larger LEDs (all resistors 1/4 watt or smaller)

- ☐ T1 3/4 blue LED
- ☐ T1 3/4 red-green bicolor LED
- ☐ R1: 4.7K ohm
- ☐ R2: 470 ohm
- ☐ R3: 1.5K ohm
- ☐ Fuses: 3 250 ma. or smaller fuses in holders (mounted in engine compartment close to points XY, and Z)

For smaller LEDs (all resistors 1/4 watt or smaller)

- ☐ T1 blue LED
- ☐ T1 red-green bicolor LED
- ☐ R1: 15K ohm
- ☐ R2: 1K ohm
- ☐ R3: 3K ohm (all fuse specifications and resistor power ratings as above)



■ The display in my Subaru, showing the compressor is on and the fan is at high speed.



■ The DRL module attached to my Honda Odyssey's air cleaner housing. Note the position of the cooling fins. Cool air entering here will help keep the resistors cool.

a manual transmission. It extinguishes the lights when the transmission is in neutral and when the parking brake is on. I thought that I might be able to design a circuit to turn them off in reverse, as well, but realized this would be overkill.

The original DRL module I built quit very quickly. Measurement showed that the two parallel resistors had failed because (I presume) of flexing from vehicle movement. They had suffered no visible damage but read wide open. My first thought when building the replacement was to mount the resistors outside surrounded by heatsinks. However, lead routing and length ruled this out, so I epoxied the resistors (rated at 10 watts each) to the inside wall of the box and put the heatsinks on the outside directly on top of them. I encircled each resistor with two plastic straps as the epoxy dried and left them in place after the project was completed. I also epoxied the diodes to the box to avoid breaks from lead flexing during vehicle movement. Diodes 1, 2, and 4 (if used) carry only coil current; 1/2 ampere should be fine. D3 should be rated at twice the current drawn by the running lights; I used eight amps.

After I built the system, I realized I had forgotten two diodes. The first one, D5 (which must be big enough to carry the full low beam current — 20 amperes would do), prevents a short circuit to ground anywhere in the Re1-resistor-D3 circuit (which would cause the fuse to blow). A short would also ground the car's original low beam circuit, thereby endangering a lot of the lighting wiring. D5 makes sure that if the low beams are turned on through the headlight switch, the short would not ground that wiring. Although the diode is shown internally, I actually wired it outside the box. D6 (not built into this particular model) will protect the contacts of Re 2 from the reverse voltage induced in the coil of Re1 when they open. So far, I haven't had any problems with this, but when I prepare for the next generation of modules, I'll examine the contacts carefully! **NV**

module, it occurred to me that it wouldn't hurt to illuminate the running lights and taillights at a reduced voltage with the headlights, so I added a feed to them through D3. This prevents illuminating the low beams by turning on the running lights which would immediately blow the fuses, if not worse.

As a side note, my other car with the built-in DRL has

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# A Touch of SPICE

by Peter J. Stonard

The most popular computer simulation tool is called SPICE (Simulation Program with Integrated Circuit Emphasis). Simply put, it's an analog electronic circuit simulator used in IC and board-level design to predict circuit behavior.

I have used SPICE for some time in industry and quite frankly it took a bit of getting used to because it has a steep learning curve. Once I got comfortable with the process, I could judge when it was valuable (and believable) and I quickly added it to my engineering bag of tricks.

My first SPICE tools were costly, commercial implementations of the original academic SPICE software developed at the University of California at Berkeley (UCB). Today, I use a freeware version that was created and is supported by the folks at Linear Technology Corp (LTC; [www.linear.com/designtools/software/](http://www.linear.com/designtools/software/)). There are several other freeware sources for circuit simulators (that trace their roots back to UCB's SPICE engine), including Texas Instrument's TINA-TI <http://focus.ti.com/docs/toolsw/folders/print/tina-ti.html>.

LTspice is very popular and has

been downloaded more than half a million times. Plus, nearly every semiconductor house has free SPICE macro models for their own products, to be used with generic SPICE tools.

We're getting ahead of ourselves, so let's see why anyone would need these tools, and what we can expect them to do for us. This is in the context of hobby electronics, and if you have used SPICE at school or do so at work you might want to skip ahead. My goal in this article is a transition from simple circuit theory with a pocket calculator to running the same circuits in SPICE (see the sidebar "Getting Started with LTspice").

## Experience Counts

An effective way to do something is to employ an expert or learn from an expert. That's all well and good, but we would be limited to only doing things that are already known. A better approach is to conceive of an idea, try it out, and make corrections when and where we got it wrong. This is called Research and Development (R&D). It offers a way to make incremental progress, but takes time and resources (money,

materials, labor, and usually more money). Another way to reach a goal is to prepare a scale model of the end product, test it for suitability, and then scale it up to final size. Models can easily look exactly like the final full size project, but making them work exactly that way is not always possible. For example, a model of a road bridge may be the right size (scale) but may not have the right strength of materials. Once understood, these limitations can be ignored (if trivial) or factored in to make the scale model behave like the real thing.

To understand the model, we can break it down into smaller parts and materials. These are collectively called elements and represent the smallest component. Practical electronic circuits also have elements, many of which are very common and well understood (such as resistors). From time to time, we may have to invent new elements for our library, as new electronic components appear in the market, for example.

A very useful tool was adapted to this type of work and it is called simulation. It can take many forms, but the idea is that a machine of one type is made to behave like that of another

type (the unknown target, in many cases). Unknown design questions can be answered and data collected before the final project is attempted. What does this have to do with hobby electronics and SPICE? Hopefully, we've added a few technical terms and some background to make it easier to understand the SPICE world (hint: element, model, simulation). These terms will appear in SPICE work, and each has a specific meaning and job to do.

## Virtual Simulator

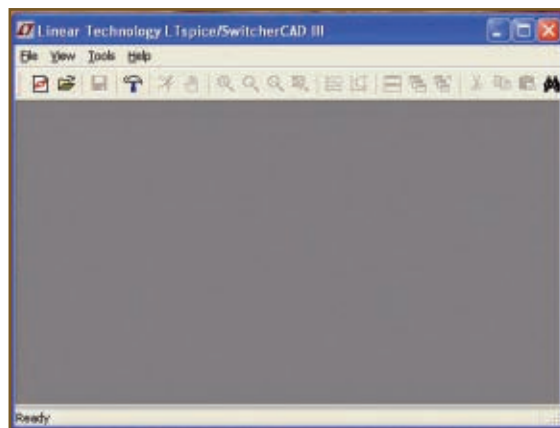
We've talked about physical machine simulators, but simulation can also be done in a totally artificial environment inside a computer, where the output is the result of mathematic operations performed upon initial data

■ **FIGURE 1. SwitcherCAD III/LTspice start-up screenshot.**

using rules that mimic the behavior of the real world materials. Simulations speed up the design cycle and reduce costs, and those advantages apply directly to all of us. Now we're getting closer to electronics! Take the principles of electronic circuits, the behavior of the components, add a schematic and power supplies, input controls and signals, add a little SPICE, and see what comes out!

## Jumping In With Both Feet

That's enough background to set



the stage. Let's try to do something simple with LTspice. Take another look at the sidebar, download the software, and set it up on your own PC. Next, start the program and compare your screen to Figure 1. Hit the File > New Schematic button on the toolbar to start a new project, and notice that

## Getting Started With LTspice

I use a typical PC running a Microsoft OS. I'm not sure if the LTspice software can run on other platforms. A fast machine (Pentium4, 2 GHz or higher) is very desirable as SPICE work hogs both memory and CPU time. The software is a free download from the Linear Technology (LTC) website at [www.linear.com/design-tools/software/switchercad.jsp](http://www.linear.com/design-tools/software/switchercad.jsp).

The tool is one of several that LTC offers, and seems to have two names: LTspice and SwitcherCADIII. As far as I can tell, they are one and the same; to avoid confusion, I'll call it LTspice (except where another name is critical, such as files and directory names). Users have the option of registering with LTC for email notification of updates, and also to download other software and device libraries (recommended).

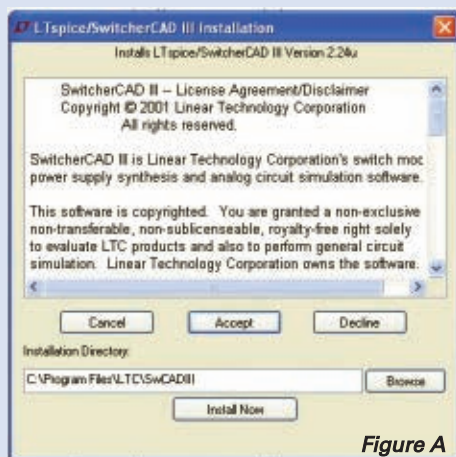
The file is about eight megabytes (it varies with updates: at the time of writing the version is 2.24u and dated 7/8/08). I recommend downloading and saving the file to a

new temporary subdirectory, then running it so if anything goes wrong (or you move it to another computer later), you already have the file saved.

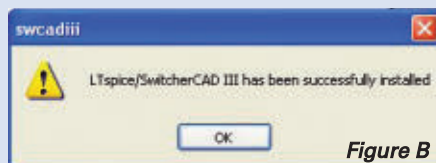
There is a legal agreement screen that requires acceptance, and the default installation is to a new subdirectory called LTC in your computer's Program Files directory. (See Figure A.) If you have already installed a previous version, it prompts before overwriting it (recommended). There's quite a bit to the automatic installation, so be patient! (Also, it's better to not tax your computer by running other programs during installation.)

When the installation has finished (Figure B), you may run the program and, for future ease, add the LTC spice icon to your computer's start menu (or desktop). The download also includes subdirectories for examples and lib (library); the LTC directory should look something like Figure C.

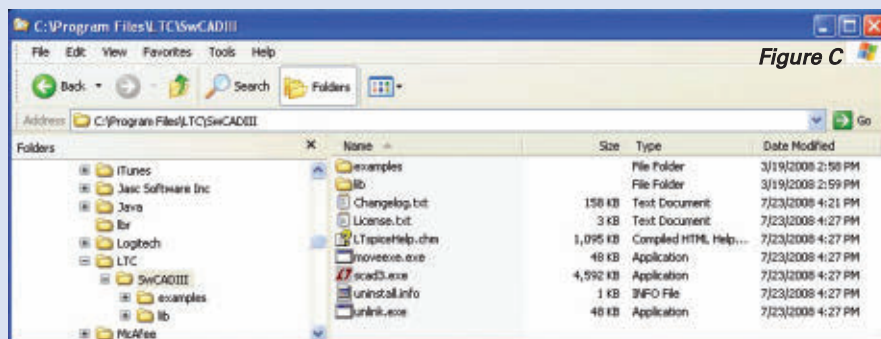
Next, navigate to the *Nuts & Volts* website with your browser and download the companion file for this article. Unzip the file to a local directory. (You can use the same subdirectory as the LTspice install (Figure C again) and put the article files and your new work in a fresh subdirectory. (I call mine NandV.)



**Figure A**




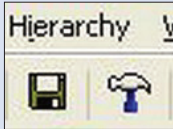
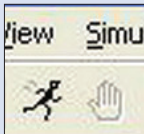
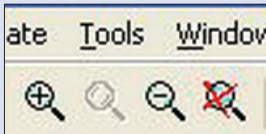


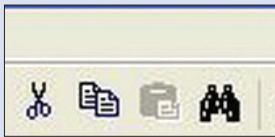
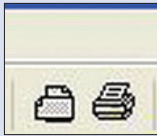
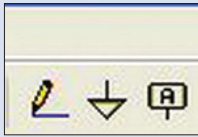
**Figure B**



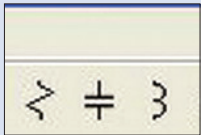
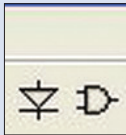



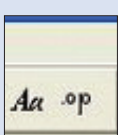
**Figure C**



## LTspice/SwitcherCAD III Button Icon Cheat Sheet

ICON	FUNCTION
	Click the <b>LT icon</b> to start a new project. In the first instance, it will be called "Draft1.asc."  Click the <b>Folder icon</b> to open an existing project. The default location is the last one used to save a project.
	Click the <b>Disk icon</b> to save a project.  Click the <b>Hammer icon</b> to invoke the control panel. We will not change from the defaults as these options are intended for advanced users. Remember to restore defaults if you do experiment with any settings.
	To run a simulation that has already been defined (with a <i>spice directive</i> in the project) — or by use of the Simulation drop-down menu — click the <b>Running Man icon</b> . To stop a running simulation, click the <b>Halt icon</b> .
	Use this set of four icons to zoom in or out while in either the schematic editor window or the simulation results window (only available after running a simulation).  The <b>Zoom + icon</b> will require a target rectangle to be drawn; the <b>Pan icon</b> maintains the scale but shifts the viewing screen area; and <b>Zoom - icon</b> zooms out. The <b>X'd-out zoom icon</b> expands the image to fill the available window area and is <i>called "zoom full extends"</i> .
	When a simulation is completed, use the <b>Pick Visible Traces icon</b> to select what signals to display. To add more than one, hold down the Cntrl key. Use the <b>Autorange icon</b> to maximize the traces on the visible graph axes.
	These buttons change the display when more than one window is available (if more than one project is open or if a project's simulation has been run). Use the <b>"Tile Windows" icon</b> to view all windows at once; use the <b>"Cascade Windows" icon</b> to stack the windows; and use the <b>"Close All" icon</b> to clear the work area but keep the program open (it will prompt to save any new work before closing Windows).
	Use this group of controls to edit a schematic. The clipboard is a good way to build a new schematic or add on to it; the <b>Cut icon</b> and <b>Copy icon</b> require a rectangle around the area of interest. The <b>Search icon</b> has a dialog box for text searches of component designators (R1, Q1, etc.) or Net names (V1, OUT, etc.), or even component values (10K, etc.).
	Use these icons to output to your computer's printer. Also, under the <b>Tools</b> drop-down menu is a useful <b>"Copy Bitmap to Clipboard"</b> function which easily allows the current project to be captured as a graphic. Use it to post your work to an online forum or into a Word doc, etc.
	These are the basic drawing tools. The <b>Wire icon</b> is used to connect components and the <b>Ground icon</b> adds at least one ground or common node to a new schematic. It may be used multiple times to link any components to ground and avoid clutter in a schematic. The <b>Label Net icon</b> is a useful way to make a schematic more readable. For example, use the label <i>"OUT"</i> in place of <i>v[n001]</i> .

## LTspice/SwitcherCAD III Button Icon Cheat Sheet *Continued*

ICON	FUNCTION
	Here are the basic passive building blocks: a resistor, a capacitor, and an inductor. Remember to give the new component a value once it's placed. Then, use the right mouse button to enter the component's description dialog. Most components also have a Select button to pick from a database of predefined standard values.
	The <b>Diode icon</b> requires a selection of a specific diode model from the database. The <b>Component icon</b> invokes a dialog box to select from the component model database. The component can be of two classes: Spice symbols (a <b>voltage generator</b> for example) or commercial components (a LM741 op-amp, for example).
	The 'hands' allow editing of an existing schematic. The <b>Move icon</b> (open hand) grabs a component and severs the connections. The <b>Drag icon</b> (closed hand) maintains the connections with rubber bands. Both act on single components or can lasso a group. Use these to clean up or edit a schematic.
	Mistakes in editing can be corrected with the <b>Undo icon</b> and <b>Redo icon</b> , which are un-ghosted during some editing steps.
	For better appearance, parts can be positioned in the schematic using the <b>Rotate icon</b> or <b>Mirror icon</b> .
	Both of these icons invoke the same dialog box, but have quite different effects. The <b>Text icon</b> is used to add annotation to a schematic without affecting the simulation. The <b>SPICE Directive icon</b> allows an instruction to be added to the schematic that controls how the simulation is run.

the toolbar icons will be un-ghosted. Now hit the Tile Windows toolbar button to bring our blank schematic to full screen size. For clarity, I'll refer to the icon buttons by name (refer to the sidebar for an LTspice button icon cheat sheet). Don't forget to download the example circuits to be used in this tutorial from the *Nuts & Volts* website ([www.nutsvolts.com](http://www.nutsvolts.com)) – this will speed things up so that you learn the schematic drawing tools later while playing with these examples.

Our first circuit simulation demonstrates Ohm's Law. We are going to do some work with a virtual resistor or two, using a virtual battery and a virtual meter to read voltage and current. This will all happen inside the

computer, so the next problem to overcome is how do we see the results? Actually, first we have to tell SPICE what we want it to do.

Fortunately, LTspice uses a GUI (Graphical User Interface) running under Windows. The original Berkeley SPICE was run on a UNIX box and humans had to type the circuit (called a netlist) and device models in as text that could be interpreted by the computer. We're already familiar with schematics that use symbols to represent electrical components and connections. These don't look like the physical parts (in most cases) and it's also true of the elements in a SPICE schematic. Where the schematic for a real world device can call out a part

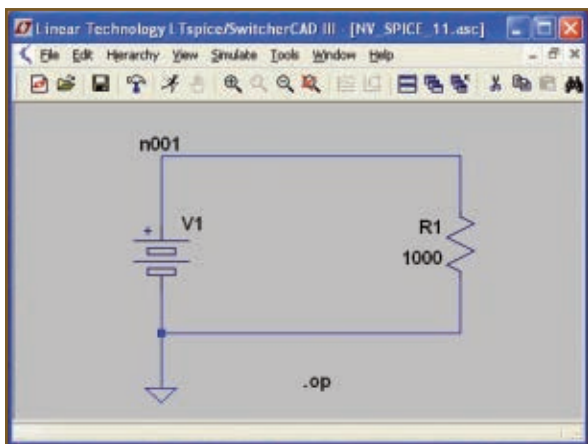
number and a symbol – a 9V battery, for example – the SPICE program has to know how a 9V battery behaves in the simulator to make sense of it in the real world. So, let's start there.

Take a shortcut by loading the schematic called NV\_SPICE\_11.asc. Although very simple, it may have taken you a while to create exactly this with the LTspice drawing tools. Having said that, don't let me stop you from doodling! The final schematic should look like Figure 2.

### Real World 9V Battery

Next, we'll explore a real world 9V battery. You'll need a DMM (Digital Multimeter), a fresh 9V





■ FIGURE 2. Schematic for NV\_SPICE\_11.asc.

thought to be 9V, but it sags under load because it has internal resistance. A 9V battery model in SPICE would be created from two elements: a perfect voltage source and a series resistor. Together these simulate the real world 9V battery for our purposes. If the real world battery was in continuous use, the initial voltage

battery, and some resistors (1W 1% 10 $\Omega$ , 1/4W 1% 100 $\Omega$ , 1/4W 1% 1K, and 1/4W 1% 10K – a few of each). For this exercise, a small solderless protoboard is very handy (Figure 3).

Start by measuring and recording the battery voltage. It should be 9.0V, right? Don't be surprised if a fresh battery reads a little higher. I now get 9.160V, but the first time through the exercise I got 9.477V! Now load the battery with a 1K resistor. The battery is still as before, but our meter reads a little less (I get 9.120V). Change the resistor to 100 $\Omega$ , read it again, and it drops more (I get 8.924V). Now try 10 $\Omega$ , and make it a one watt size as a fresh 9V battery can toast a single 1/4W resistor! Hmm, the battery voltage is dropping quite a bit (I get 7.605V and declining). Disconnect the battery! Our real world battery was

would fall until the battery is exhausted. Perhaps that is chosen to be around 7V. Later, we can simulate this in SPICE by running the program twice (once at 9V and again at 7V) to judge what a nearly dead battery does in our circuit. In summary, our SPICE program must model these secondary characteristics of the real world battery to be useful and believable as a tool. For advanced SPICE users, most of the time is spent on refining models and worrying about minute but important behavior of real world components! The old computer adage is "Garbage In, Garbage Out," and that holds true for SPICE.

## Ohm's Law

We know that the relationship between voltage and current in a DC circuit is governed by

Ohm's Law. Lowering the resistance increases the current and vice versa. Intuitively, we also know that two equal value series connected resistors will divide the voltage equally. The total circuit current drops to one half that of using just one resistor.

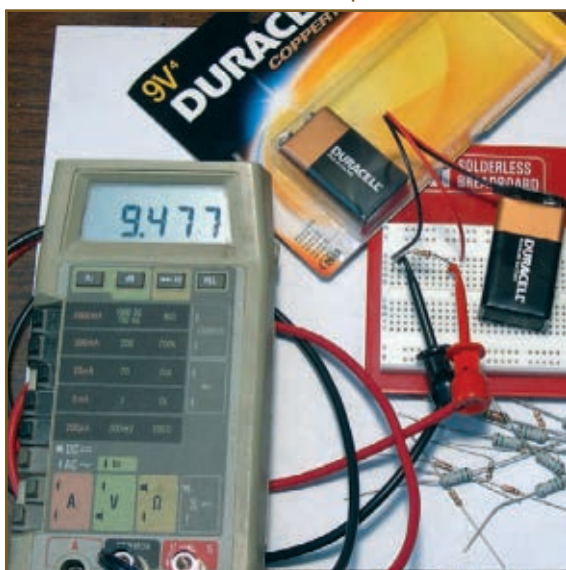
Likewise, placing two resistors of equal value in parallel will double the circuit current. If your DMM

and battery are still handy, try some of these intuitive experiments (resistors of the same value placed in series and parallel). Use 10K resistors to minimize the effect of internal battery resistance and to save that battery for future experiments. Next, we'll build the same circuits using their SPICE equivalents, run the simulation, and extract the results. Because these are simple DC circuits, we ask LTspice to calculate the initial conditions (using the SPICE directive ".op"), and the simulation takes no time at all to finish. With NV\_SPICE\_11.asc, start the simulation by hitting Run. A new window will pop up (see Figure 4) with our results. What does this tell us? The item called n001 is a circuit Net (a connection of two or more components), and any connection point on a Net is called a Node. It is the connection from the battery to the resistor. In the real world, we'd read it by touching the meter probe with the other meter lead going to common (sometimes called ground). This is an important point; all SPICE schematics must have one common connection. For ease of drawing, we can use the common symbol multiple times to mean all are connected to the same Net. Because there's a V in the description, we are measuring voltage and it's just under 9V. The other two lines are currents (I symbol) and are the current in the resistor (R1) and the battery (V1). As simple as this seems, it tells us a great deal. Firstly, we have eight digits after the decimal, indicating we know the value down to tens of nano-amps. SPICE has this level of precision math which is needed in advanced topics, but makes our simple circuit results a bit confusing to read. Next, we see that the battery current is negative. We didn't put the battery in backwards; what does this mean?

Conventional Current is said to flow from positive to negative, but electron flow is from negative to positive. SPICE tells us that the

electron current is flowing from the

■ FIGURE 3. Breadboard set-up.



-- Operating Point --

V(n001) :	8.88889	voltage
I(R1) :	0.00888889	device_current
I(V1) :	-0.00888889	device_current

■ FIGURE 4. Results table for NV\_SPICE\_11.asc.

negative terminal of the battery, towards positive, and passes through resistor R1 last. Also, Kirchhoff's second rule: The directed sum of the electrical potential differences around any closed circuit must be zero. Finally, we get a taste of how SPICE data is presented. For most hobby applications, the number precision and terse formatting can be a bit of a turn-off, but don't give up as it will soon become second nature!

We can place our own labels on Nets, using the Label Net tool as we will see in NV\_SPICE\_12.asc, which should be loaded after closing the results window and saving your first simulation results. I've also swapped the battery symbol for the pure voltage generator symbol — a more popular SPICE graphic. For clarification, I've shown the battery internal resistance as an extra resistor (R1) and added all three load resistors at once (see Figure 5). Run the simulation and save your results. Take a look at them in Figure 6. Notice the resistor's values are in decades (10, 100, 1000), and the corresponding currents are also in decades.

## Taking The Circuit's Pulse

The last exercise for this session is to replace the SPICE "battery" with a signal generator. In SPICE, we can call up a simple sine wave generator, a swept sine wave generator, an impulse generator (a personal favorite), or a custom waveform made from various voltage segments that play out over time (and which we can also adjust at will). Loading the schematic NV\_SPICE\_13.asc, notice the voltage generator has more text (Figure 7). This is the SPICE directive to define the waveform from the generator. I've removed the internal resistance and adjusted the generator to 10V to make the math results a bit easier to read. Run the simulation, then look at the results in Figure 8.

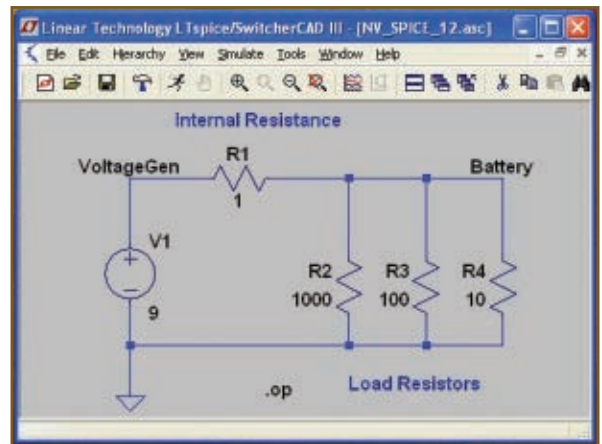
Well, something might be

■ FIGURE 8. Results table for NV\_SPICE\_13.asc.

■ FIGURE 5. Schematic for NV\_SPICE\_12.asc.

wrong as the values are all zero! What this tells us is that the SPICE operating point — or initial conditions — have no circuit voltage and indeed all the Nodes are zero volts. We need to trigger the waveform generator and let SPICE do a time sweep of the circuit while the generator is running, and this uses a different simulation type. Let's take a shortcut and just tell SPICE what to run, as the toolbar process to get there is a bit lengthy.

Using the cut command, remove the SPICE directive .op text from the schematic. Next, using the SPICE directive command found on the far right of the toolbar, enter the text .tran 100m and place it on the schematic. Anywhere will work, but I like to put these on a line under the ground symbol so they're easy to find later. Run the simulation and see that the screen now looks like Figure 9. If it's not formatted, hit Tile Windows. The simulation has run and the graphical results window is visible; we just need to request SPICE to fill in the graph traces of interest to us. Click the Pick Visible Traces toolbar button and select the V(pulsegen) Node; hit OK to create the graph shown in Figure 10. At this point, it might help to expand the plot window to full screen using the Maximize button in the top right-hand corner of the plot window.



### — Operating Point —

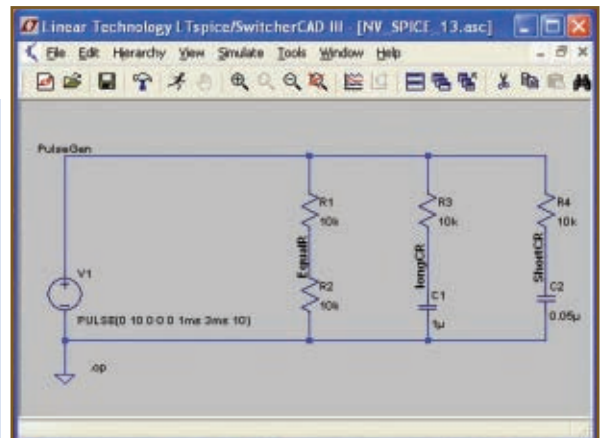
```
V(voltagegen): 9 voltage
V(battery): 8.10081 voltage
I(R4): -0.810081 device_current
I(R3): -0.0810081 device_current
I(R2): -0.00810081 device_current
I(R1): -0.89919 device_current
I(V1): -0.89919 device_current
```

■ FIGURE 6. Results table for NV\_SPICE\_12.asc.

## Understanding The Simulation Results

What do we see? This is the time sweep of the circuit from zero to 100 milliseconds. During that time, the pulse generator produced 10 pulses of 1 ms duration and 2 ms rest between pulses, and then stopped. The pulses are 10V amplitude and the node EqualR (with two resistors each of 10K) divides the pulse amplitude in half (5V). To see both traces at once,

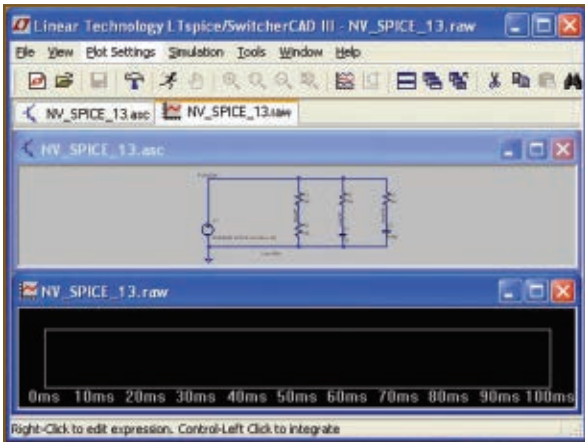
■ FIGURE 7. Schematic for NV\_SPICE\_13.asc.



### — Operating Point —

```
V(pulsegen): 0 voltage
V(longcr): 0 voltage
V(shortcr): 0 voltage
V(equalr): 0 voltage
I(C2): 0 device_current
I(C1): 0 device_current
I(R4): 0 device_current
I(R3): 0 device_current
I(R2): 0 device_current
I(R1): 0 device_current
I(V1): 0 device_current
```





■ FIGURE 9. Results plot for NV\_SPICE\_13.asc.

constant” and a “long time constant.” Experiment with the Pick Visible Traces to see the effect of these components on the pulses.

## Oscilloscope Analogy

Using the graph is much like running an analog scope. We have control over the Node (scope probe placement), horizontal scale (time-base), and vertical scale (Y amp gain). Plus, this scope is always in calibration and we can print the results to paper, if desired. LTspice does have a graphical probe tool, too. Activate the schematic window so the border is dark blue instead of ghosted out, and mouse over the schematic’s wires. The

mouse pointer changes to a probe icon, and if you then select that trace by clicking, the waveform will be added to the results window graph. Very neat!

An advanced scope with dual delay timebases can let us see a selected piece of the displayed waveform. So too, can LTspice expand the graph’s details. Using the mouse and holding the right mouse button, grab a piece of the graph waveforms. When the area is selected, the graph scales

to just that view as shown in Figure 11. To restore the full graph, hit the toolbar button Zoom Full Extends.

## Current Probe

With a conventional scope, we use the probe to view the voltage (usually with respect to ground or common). To see the current in a live circuit, we’d need a fancy current probe which works with our usual voltage scope. In LTspice, we can readily view the current flowing through a component by placing the mouse over it. Previously, we selected wires, saw the probe icon, and got voltage on that node; while over a component, the current source icon appears and we get the current flowing through the component.

The results are plotted on the same graph as the generator voltage waveform in Figure 12. Notice the Y axis is labeled in volts on the left for the V(pulsegen) trace and in milliamps on the right for the I(C1) current trace.

## Wrap Up For This Session

I encourage everyone to poke around in the LTspice environment, and experiment with the mouse buttons. Right-clicking while hovering over components or graphs will open dialog boxes not discussed here yet. (Just remember to save your own work under different names, to preserve the files used here in the tutorials.)

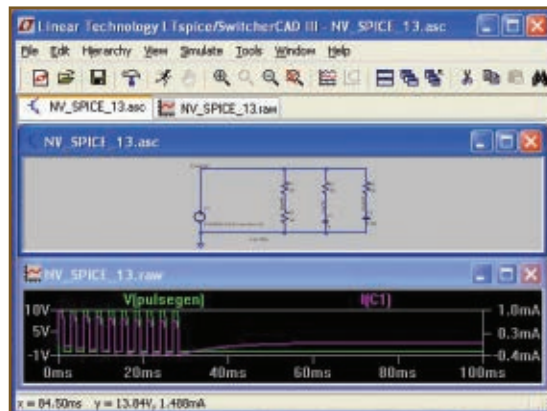
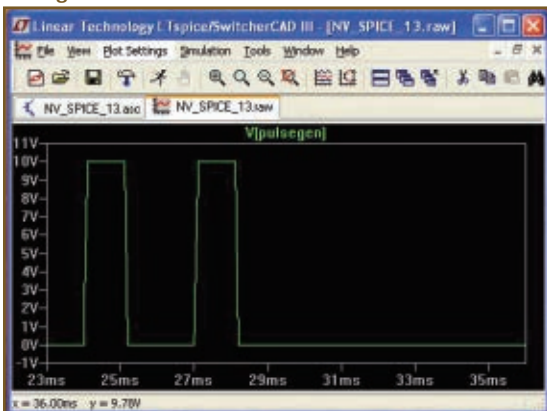
Have a question? Please contact the author via email (pstonard@ix.netcom.com). Or, join us online at the

Nuts & Volts forum (<http://forum.servomagazine.com/>). In the next installment, we’ll use LTspice to simulate two very popular analog ICs, and introduce the concepts of sub-circuits and macro models. **NV**

■ FIGURE 10. Adding the trace V(pulsegen) to the plot screen.

go back to the Pick Visible Traces toolbar button and select the V(pulsegen); while holding down the Cntrl key, also select EqualR. Many traces can be added, but too many and the graph becomes hard to read. In the other branches of the circuit, I added capacitors, and together with the resistors these form a “short time

■ FIGURE 11. View of selected portion of Figure 9.



■ FIGURE 12. Combination voltage and current traces.



# SMILEY'S WORKSHOP

AVR MICROCONTROLLER: C PROGRAMMING - HARDWARE - PROJECTS

by Joe Pardue

Get started now with this series! Joe's book & kit are available in our webstore at [www.nutsvolts.com](http://www.nutsvolts.com)

## PART 5:

There are exactly 10 types of people in the world: those who understand binary and those who don't.

■ FIGURE 1. Ten types of people.

Last month, we learned some more C syntax, a bit about libraries, and taught our Butterfly to talk. This month, we are going to learn what the heck that button in Figure 1 means. AND, the first binary 1000000 folks who ask will get the button for free.

See [www.smileymicros.com](http://www.smileymicros.com) for details. If this doesn't make sense to you now, it will in a minute (or two).

### Bitwise Operators

Bitwise operators are critically important in microcontroller software. They allow us to do many things in C that can be directly and efficiently translated into microcontroller machine operations. This is a dense topic, so get out a pencil and piece of paper and work through each of the examples until you understand it.

In case you've ever wondered how to tell what is true and what is false — well for bitwise operators which use binary logic (single bits) — 1 is true and 0 is false.

We discussed binary vs. hexadecimal vs. decimal in Workshop 3, but to refresh: A byte has 256 states numbered 0 to 255. We number the bits in a byte from the right to the left as lowest to highest:

```
bit #      76543210
myByte = 01010101 binary = 0x55 hexadecimal = 85
decimal
```

Look at the truth tables for AND '&', OR '|', XOR '^', and NOT '~':

AND	OR	XOR	NOT
0 & 0 = 0	0   0 = 0	0 ^ 0 = 0	~1 = 0
0 & 1 = 0	0   1 = 1	0 ^ 1 = 1	~0 = 1
1 & 0 = 0	1   0 = 1	1 ^ 0 = 1	
1 & 1 = 1	1   1 = 1	1 ^ 1 = 0	

Now memorize them. Ouch, but yes, I am serious.

There are exactly 10 types of people in the world. Those that understand binary and those that don't.  
[www.smileymicros.com](http://www.smileymicros.com)

### ORing

We can set bit 3 to 1 in a variable, myByte, by using the Bitwise OR operator: '|'

```
myByte = 0;
myByte = myByte | 0x08;
```

To see what's happening, look at these in binary:

```
bit #      76543210
myByte = 00000000 = 0x00
0x08 = 00001000 = 0x08

OR = 00001000 = 0x08
```

We see that bit 3 is 1 in 0x08 and  $1 | 0 = 1$ , so we set bit 3 in myByte.

Suppose myByte = 0xF7:





Operator	Name	Example	Defined
~	Bitwise complement NOT	~x	Changes 1 bits to 0 and 0 bits to 1.
&	Bitwise AND	x&y	Bitwise AND of x and y
	Bitwise OR	x y	Bitwise OR of x and y
^	Bitwise exclusive OR	x^y	Bitwise XOR of x and y
<<	Left shift	x<<2	Bits in x shifted left 2 bit positions
>>	Right shift	x>>3	Bits in x shifted right 3 bit positions
TABLE 1. Bitwise Operators.			

```

bit #      76543210
myByte = 11110111 = 0xF7
0x08 = 00001000 = 0x08
-----
OR = 11111111 = 0xFF

```

Or maybe myByte = 0x55:

```

bit #      76543210
myByte = 01010101 = 0x55
0x08 = 00001000 = 0x08
-----
OR = 01011101 = 0x5D

```

This shows that only bit # 3 of myByte is changed by the OR operation. It is the only bit equal to 1 in 0x08, and ORing 1 with anything else is always yields 1, so you can use it to 'set' a bit regardless of that bit value.

## ANDing

Now let's do the same thing with the & operator: We can clear bit 3 with:

```

myByte = 0xAA;
myByte = myByte & 0xF7;

bit #      76543210
myByte = 10101010 = 0xAA
0xF7 = 11110111 = 0xF7
-----
AND = 10100010 = 0xA2

```

Or maybe myByte = 0x55:

```

bit #      76543210
myByte = 01010101 = 0x55
0xF7 = 11110111 = 0xF7
-----
AND = 01010101 = 0x55

```

From this, you see that ANDing with 1 leaves the bit

value the same as the original bit and ANDing with 0 clears that bit regardless of its state. So, you can use ANDing with 0 to 'clear' a bit value.

Setting and clearing bits is very important in AVR microcontrollers since the plethora of peripherals available are set up by either setting or clearing the hundreds of bits in dozens of byte-sized registers.

## Setting and Clearing Bits

In each of the above cases, we are only dealing with a single bit, but we might be interested in any or all of the bits. Another important feature of using bitwise operators is that it allows us to set or clear a specific bit or group of bits in a byte without knowing the state of nor affecting the bits we aren't interested in. For example, suppose we are only interested in bits 0, 2, and 6. Let's set bit 6, regardless of its present value, then clear bits 0 and 2, also regardless of their present value. Here's the trick: We must leave bits 1, 2, 4, 5, and 7 as they were when we began.

NOTE:

```
myByte = myByte | 0x08;
```

is the same as

```
myByte |= 0x08;
```

which we will use from now on. To set bit 6, we OR myByte with 0100000 (0x40):

```

myByte = 42;
myByte |= 0x40;

bit #      76543210
myByte = 00101010 = 0x2A
01000000 = 0x40
-----
OR = 01101010 = 0x6A

```

Next, we want to clear bits 0 and 2 so we AND 11111010:

```

myByte &= 0xFA;

bit #      76543210
myByte = 01101011 = 0x6B
0xFA = 11111010 = 0xFA
-----
AND = 01101010 = 0x6A

```

So, in summary, we set bits with '|' and clear bits with '&'.

If you are going 'Oh my God!' at this point, I hope it

is because you are surprised that you actually understand this. If it isn't, then get that pencil and paper and go back until you do.

## XORing

Suppose we want to flip the highest four bits in a byte while leaving the lowest four alone; we could use a mask with the bits you want to flip set to 1 and the bits you don't want to flip set to 0:

```
myByte = 0xAA;
myMask = 0xF0;

myByte ^= myMask;

bit #      76543210
myByte = 10101010 = 0xAA
myMask = 11110000 = 0xF0
-----
XOR = 01011010 = 0x5A
```

XORing is used a lot by cryptographers, but not a lot by us mortals.

## NOTing

Using the above example, we could clear those bits in myByte using the NOT on the mask, then AND it with myByte.

```
myByte = 0xAA;
myMask = 0xF0;

myMask = 11110000 = 0xF0
~myMask = 00001111 = 0x0F

myByte &= ~myMask;

bit #      76543210
myByte = 10101010 = 0xAA
~myMask = 00001111 = 0x0F
-----
AND = 00001010 = 0x0A
```

## Shift Operators

The shift operators can be used to radically speed up multiplication and division IF you use numbers that are a power of 2. You might want to do this for tasks like averaging ADC readings. When we study ADC, you'll see that sometimes we can get more accurate results if we take a bunch of readings and average them. My first inclination was to take 10 readings and then divide by 10. I chose 10 because I've got that many fingers, but if I had

chosen eight or 16, then my division would be much faster on a binary computer using  $\gg$ . If I divide by 10, the compiler has to call a large and complex division function (and maybe even involve floating-point data types) but if I divide by eight it only needs to shift bits three positions to the right. Three quick right shift operations versus lots of time and program space – the trade-off is precision.

Let's say my readings were:

54, 62, 59, 57, 60, 59, 56, 63 = 470

The sum is 470 and  $470 / 8 = 58.75$

Remember that the largest decimal number that fits in an eight-bit byte is 256, so we must store 470 in a 16-bit integer: 0000000111010110.

```
myTotal = 470

bit # FEDCBA9876543210 (in Hex)
myTotal 0000000111010110
```

If we shift this right three times, it becomes:

```
myAverage = (myTotal >> 3);

bit # FEDCBA9876543210
>> 3 0000000000111010110
```

The low three bits 110 fall out of the AVR and have to be swept up later. (You didn't believe that did you? They actually just disappear.) Anyway, the value now (ignoring the leading zeros) is 111010 which is decimal 58.

Note that 58 is not 58.75, but you did save both time and program space, so you have to decide which is better to use. The binary averaging gets you closer than all but two of the eight readings (59) and it does it lightning fast so if you are time constrained, the trade-off should be obvious.

## Masks and Macros: Using Named Bits

You probably didn't know this, but Cylon eyes don't just sweep a single LED back and forth at one speed. No, when they get excited the sweep speeds up and if they get really excited they sweep more LEDs. When they are feeling contrary, they can invert the pattern. When they get walloped up side the head, they do this weird walleye sweep. When they get really mad, the LEDs vibrate. When they get confused, they do an ant sweep. When they see an actual chrome toaster – like with bread in it – they blink all LEDs on and off. And when they get infected with Microsoft Windows, they generate random dots until reset. Finally, the sweep has 16 speeds.





We have seven patterns and we can encode them with three switches as follows:

Binary	Decimal	Pattern	Select
000	0	cylonEyes	
001	1	cylonEyes2	
010	2	cylonEyes3	
011	3	wallEyes	
100	4	antEyes	
101	5	vibroEyes	
110	6	blinkinEyes	
111	7	randomEyes	

If you want to get your Cylon Optometry Doctorate, you have to figure out how to encode those seven patterns, the 16 speeds, and the polarity using just eight switches. We will use bitwise operators, masks, and macros to do just that for our CylonOptometry.c project. So, dig out that PortI/O hardware project and reverse the wires so that DIP switch 8 goes to PORTB 0, 7 to 1, 6 to 2, and so on. Yes, sorry, but I want the switches to match the bits in a binary number like: bit #76543210 with the rightmost switch being bit 0 and the leftmost being bit 7. Figure 2 shows the switch pattern.

Now we will define bit masks:

```
// DIP switch masks
#define POLARITYMASK 0x01 // 00000001
#define SELECTMASK 0x0E // 00001110
#define SPEEDMASK 0xF0 // 11110000
```

If we AND each of these masks with the value we read on PORTB, we convert all the bits we aren't interested in to 0 and leave those we are interested in as they were in the port.

Suppose, for instance, that we set the speed to 9, the pattern select to 6, and the polarity to 1. We would see 10011011 (0x9B).

```
PORTB = 10011011 (0x9B)
```

```
bit # 76543210
```

```
PORTB = 10011011 = 0x9B
POLARITYMASK = 00000001 = 0x01
```

```
AND = 00000001 = 0x01
```

```
bit # 76543210
```

```
PORTB = 10011011 = 0x9B
SELECTMASK = 00001110 = 0x0E
```

```
AND = 00001010 = 0x0A
```

```
bit # 76543210
```

```
PORTB = 10011011 = 0x9B
SPEEDMASK = 11110000 = 0xF0
```

```
AND = 10010000 = 0x90
```

We have isolated the bit fields for each mask, but we still have one more step. You will note that the polarity can be only 0 or 1 — which is fine — but the pattern select does not directly indicate the number of the pattern since it begins at the second bit, not the first. So each value is multiplied by two. Our count is not 0,1,2,3,4,5,6,7; it is 0,2,4,6,8,10,12,14. We could use this numeric sequence to define our pattern states, but it would be much simpler if we could just shift the whole byte one position to the right, dropping the first bit into the void — and we can do that with the right shift operator `>>`. Our mask gave us: 00001010 = 0x0A. But (00001010 `>>` 1) is equal to 00000101 or for hex 0x0A `>>` 1 equals 0x06. The same idea holds true for the speed value that we right shift 4: (0x90 `>>` 4) is equal 0x09.

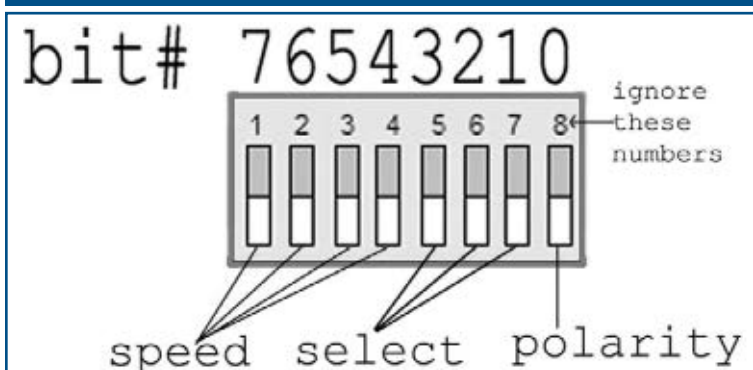
In CylonOptometry.c, we read the switch state, mask off the polarity, speed, and pattern, shift them, and then use a switch statement to select the function for the specified pattern. Each of these seven functions runs through an array containing the pattern to show on the LED and calls the dillydally() function that delays a number of milliseconds depending on the speed setting. It then checks to see if PORTB has changed. If not, it returns 0 to the function that will show the next pattern in the array. If PORTB has changed, then it returns 1 and the function will return to main(),

and run the switch statement again to see if a new pattern has been selected.

The following is from the cylonEyes section of the program:

```
/*
00000001 == 0x01
00000010 == 0x02
00000100 == 0x04
00001000 == 0x08
00010000 == 0x10
00100000 == 0x20
01000000 == 0x40
10000000 == 0x80
01000000 == 0x40
```

■ FIGURE 2. DIP switch use.



```
00100000 == 0x20
00010000 == 0x10
00001000 == 0x08
00000100 == 0x04
00000010 == 0x02
*/
void cylonEyes()
{
uint8_t i = 0;
uint8_t ce[] = { 0x01, 0x02, 0x04, 0x08, 0x10,
0x20, 0x40, 0x80 };

while(1)
{
// run up the array
for(i = 0; i <= 7; i++)
{
if(dillyDally())
return;          // delay or bail
if(Polarity)
PORTD = ce[i];  // show non-invert
else
PORTD = ~ce[i]; // show inverted
}
// run down the array
for(i = 6; i >= 1; i--)
```

```
{
if(dillyDally())
return;          // delay or bail
if(Polarity)
PORTD = ce[i];  // show non-invert
else
PORTD = ~ce[i]; // show inverted
}
}
```

Whoa, we were having so much fun that we've run ourselves plum out of space. The rest of the CylonOptometry software and a text supplement is in CylonOptometry.zip that you can download from *Nuts & Volts* at [www.nutsvolts.com](http://www.nutsvolts.com) or [www.smileymicros.com](http://www.smileymicros.com).

By now, you should know what Figure 1 means, binary 10 people is decimal 2 people, and that giving away binary 1000000 buttons isn't such a big deal since it's decimal 64 buttons. If you email your address to [nv@smileymicros.com](mailto:nv@smileymicros.com) and are one of that first binary 1000000, I'll send you a button for free. A note for Vista users and those folks who want to use the most recent WinAVR and AVRStudio: You can download from [www.smileymicros.com](http://www.smileymicros.com) 'New Quick Start Guide' and 'C Projects Source Code for Vista.' **NV**



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# "How To" BASICS

## BREADBOARDING

by Fred Eady

I'm old enough to have experienced black and white television, the introduction of color television, the very first post-WWII gasoline "shortage" and rotary "Princess" telephones. I also remember when AM radio was king and only uppity college kids listened to FM. In fact, I recall when an AM radio was all the entertainment you would ever find installed in the automobile dashboards. In my youth, a CB radio was your cell phone and your iPod was an eight-track tape player. My buddies and I questioned the ability of those tiny new audio cassettes to sound as good as our vinyl records and quarter-inch reel-to-reel tapes. Oh yeah, that vinyl album costs \$3.98, which I considered highway robbery. After all, gasoline prices had just been raised and I was paying 25 cents a gallon for that 23 cent-a-gallon gas I just bought last week. With those high prices, how could I afford to buy the latest tunes and cruise the Dairy Queen parking lot in my brand new \$4,000 Oldsmobile 442?

Yes, I'm old and I wish I still had that 442. However, I'm not old enough to remember ever being forced to assemble an electronic circuit on a piece of wood. Depending on who you trust and what you believe, electronic assembly — both hobby and professional —

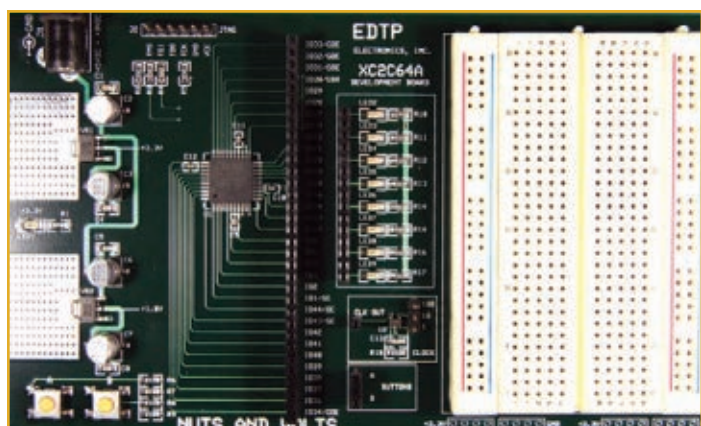
began with a foundation of an easily acquired and just as easily cut-to-size slab of wood. In addition to being sturdy, workable, cheap, and plentiful, dry wood is a fairly good insulator, which made it an ideal choice for supporting the screw-down point-to-point construction techniques used at the time.

Modern breadboard derivatives are constructed with plastic that is formed around a spring-loaded metal conductor. The plastic is molded to form rows and columns of single-pin, spring-loaded sockets that are designed to get an electrical grip on standard hookup wire. The plastic and metal breadboard sockets are also amiable to common leaded electronic components such as resistors, transistors, and capacitors. Note that I listed the components as "leaded." You can't squeeze a solderless breadboard connection out of an SMT resistor, an SMT transistor, or an SMT capacitor without first soldering some wires to them.

Modern plastic-based solderless breadboards are intended to be reusable universal circuit assembly platforms. I often use solderless breadboards for quick and dirty proof of concept verification. As you can see in Photo 1, I sometimes use plastic solderless breadboards as a reusable breadboard area on development board projects. Although the modern plastic-based breadboards are excellent platforms for most prototyping tasks, we won't be breadboarding our circuit on a solderless breadboard this time around.

### No Splinters

Now that we've eliminated solderless breadboards



■ PHOTO 1. This Xilinx CPLD development board includes an integral solderless breadboard. The solderless breadboard allows the designer to quickly build up peripherals and interfaces to interact with the development board's CPLD.

from our immediate discussion, you can put that circular saw away as we won't be screwing down any of our electrical components into a slab of pine. We're about to delve into some 21st century breadboarding.

If you've ever shopped for project parts at RadioShack, you are already familiar with their breadboards. RadioShack calls them perfboards. We'll call them breadboards. An example of a RadioShack breadboard caught the attention of my camera in Photo 2. The phenolic RadioShack breadboard depicted in Photo 2 is most likely designated as FR-2; FR in this case indicates it is flame resistant and 2 is telling us that the perfboard is made of synthetic resin bonded paper.

Other than being rated as FR-2, the phenolic breadboard in Photo 2 is single-sided. That is, it presents unplated copper pads on one side only. Since there is only copper on one side of the board and there is no plating on the copper pads, a plated-through pad cannot exist on this breadboard. Thus, the RadioShack breadboards are equivalent to a single-layer printed circuit board (PCB) with no plated-through holes. These boards work very well for general-purpose breadboarding of standard leaded components. Some of the breadboards can also handle the mounting of SMT components if you choose a suitable copper pad arrangement.

If you don't have access to a local RadioShack, you most likely use mail-order electronic vendors such as ([www.jameco.com](http://www.jameco.com)) or Mouser ([www.mouser.com](http://www.mouser.com)) to get your electronic parts fix. You will find a breadboard for almost any application within the pages of their catalogs. For instance, you'll find a large selection of breadboards constructed using epoxy resin. These glass/epoxy breadboards are normally designated FR-4. The number 4 signifies that the PCB material is composed of woven glass reinforced epoxy resin. An FR-4 breadboard posed for Photo 3. The good news is that all of the basic techniques associated with breadboarding can be performed equally as well with an FR-2 breadboard as they can with an FR-4 breadboard. However, a breadboard with plated-through holes does have its advantages.

## Tooling Up

The goal of breadboarding is to mount electronic components on a supporting substrate and make all of the necessary electrical connections that result in a functional electronic device. In most cases, a length of wire is used to make an electrical connection between components mounted on a breadboard. Before the wire is installed in the circuit path, the wire must be cut to length and if the

wire is insulated, it must be stripped at both ends to expose enough of the wire to attach and solder it to each end of the electrical connection. Cutting, stripping, positioning, and soldering wires make up the bulk of breadboarding work. All of the mail-order electronics outlets and local RadioShacks offer electronic hand tools to help you with manipulating breadboard wiring. I have also found that local home centers stock high quality wire cutters, lead cutters, and pliers that work well in the breadboarding environment. Since good solder joints are a must for point-to-point electronic assembly, I suggest investing in a good quality soldering station. Check the pages of *Nuts & Volts* and you'll find a number of vendors that can help you put a reliable soldering station on your bench. The bottom line in tool selection is quality. I know from experience that when those cheap lead cutters go dull in the middle of an important breadboarding project, you'll wish that you had spent that extra couple of dollars for a higher quality tool.

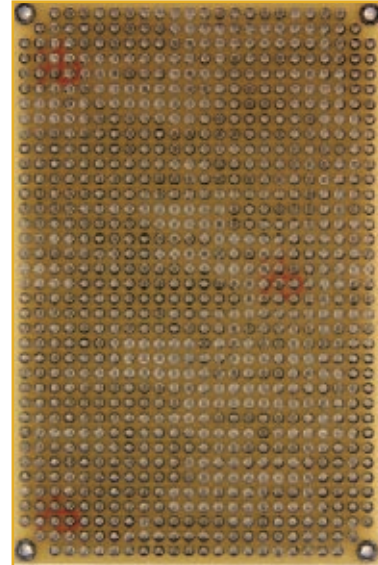
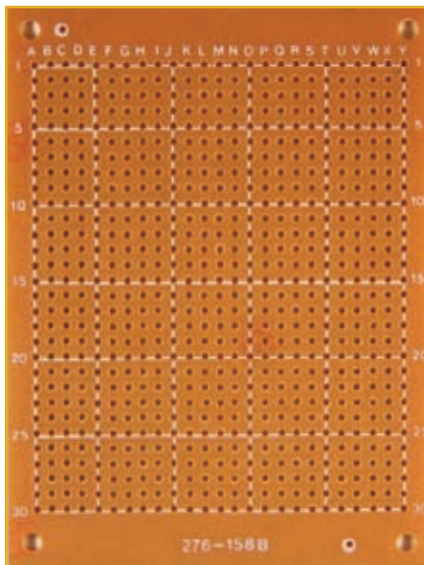
## Breadboarding 101

I'm not going to insult your intelligence by detailing the process of mounting a component on a breadboard and wiring it in. However, I will pass along some breadboarding wisdom:

- Rats nest wiring techniques insure breadboarding failure.
- Poor component layout insures breadboarding failure.
- Sloppy soldering techniques insure breadboarding failure.
- Never begin a breadboarding project until you have all of the components in hand.
- Route your breadboard wiring as if you were

■ **PHOTO 3.** This FR-4 breadboard consists of 0.046 inch diameter plated through-holes, which are dispersed on 0.1 inch centers. The through-hole solder plating enables electrical continuity between both sides of the breadboard at every hole. Thus, this breadboard can be considered as double-sided with plated through-holes.

■ **PHOTO 2.** The copper pads on the other side of this perfboard are not solder-plated. So, you'll need to clean the copper pads with a Scotch-Brite pad before attempting to do any serious breadboarding with this perfboard.





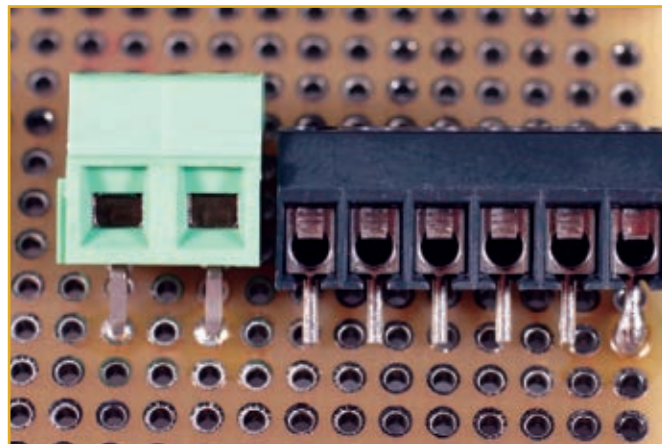
laying out printed circuit board traces.

You've finished wiring up your circuit and nothing works. If you've haphazardly laid in your connections, you'll have to dig out an ohmmeter to find and check your circuit paths. To avoid having to tear apart your work to find a wiring bug, try to lay out your point-to-point wiring just as if each wire was a trace on a PCB. If you took the time to logically locate the electronic components and connectors on your breadboard, tracking wires on the breadboard as if they were PCB traces is logical and comes naturally. Soldering in a rats nest of wire will certainly result in a shorted pair of wires or a cold solder joint. Proper component layout and methodical wire routing will allow you to solder in the clear. Creating a clean and logical component layout on your breadboard cannot be achieved if you don't have all of the electronic components you need to mount on the breadboard. Without a complete component layout, you can't make logical and clean wire routing decisions.

## Working Smart

It may be painful at first, but combining SMT components with a plated through-hole breadboard like the one you see in Photo 3 can eliminate a large portion of the labor-intensive wire cutting, wire stripping, wire positioning, and soldering associated with breadboarding. Consider the LED/resistor combination I've laid down on a double-sided FR-4 breadboard in Photo 4. The LED is mounted on a 1206 SMT package. The LED's 330 $\Omega$  current limiting resistor is packaged in 0805. There are a couple of things I want to bring to your attention concerning the LED and its companion current limiting

■ **PHOTO 4.** The 0805 SMT components fit nicely between the 0.1 inch pitch plated through-holes of this breadboard, which happens to be the same FR-4 breadboard you see in Photo 3. The LED proves that you can also squeeze in larger 1206 SMT components between the holes. The ability to directly connect SMT components to each other on the breadboard eliminates wire, saves time, and makes the component layout neater and more compact. Plated through-holes also allow electrical access to components from both sides of the breadboard.



resistor. Note the absence of wire connecting the LED and the resistor. The other cool thing here is that electrical access to the LED's anode and cathode are available on the opposite side of the breadboard. The same holds true for both nodes of the resistor.

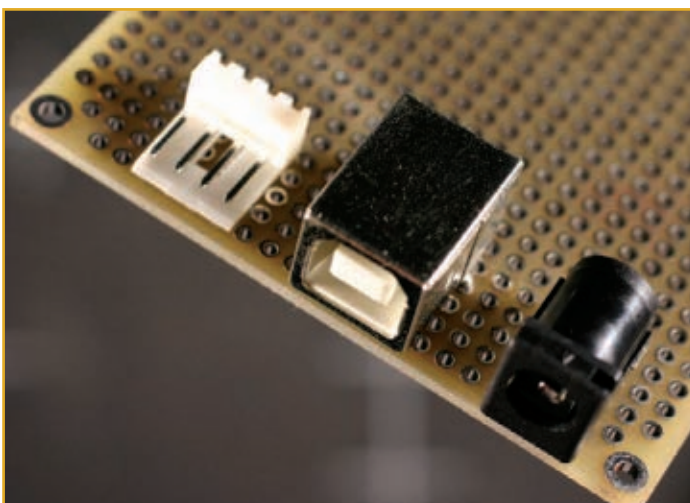
Moving to the right of the LED/resistor pair, you see a 0.1  $\mu$ F ceramic capacitor, which is packaged as 0805. In this breadboard connection simulation, the cap is representing a power supply bypass capacitor on duty between the VDD and VSS pins of a PIC18F2620 microcontroller, which would be mounted in a socket on the opposite side of the breadboard. Again, note the absence of connecting wires between the capacitor and the PIC18F2620's socket pins. No cutting, stripping, or soldering of wire was necessary as I simply nudged the capacitor between the socket pins and soldered the capacitor into the circuit. Photo 5 shows us how important it is to select components that complement the structure of the breadboard. The screw terminal block on the left is designed to mate with a 0.150 inch pitch hole pattern. It's rather obvious that we would have to break out the Moto-Tool to force fit this pitch screw terminal block onto our 0.01 inch pitch breadboard. It's much easier to drop in the 0.02 inch pitch screw terminal block on the left.

The more components you have to mount, the more stuff you have to interconnect. You can eliminate having to install power supply regulation circuitry on your breadboard by powering your breadboard with a regulated +3.3 VDC or +5 VDC wall wart. Today's PC switching power supplies are smaller and cheaper than their forefathers. Thus, you can also opt to adapt your breadboard to accept regulated +5 VDC power directly from an industry standard PC power supply interface. Did you know that you can power your breadboard with regulated +5 VDC supplied by a PC USB interface?

I've assembled all of the aforementioned power interfaces on a breadboard in Photo 6. The four-pin diskette drive interface is a no brainer as its pins are on 0.1 inch centers and industry-standard PC power supplies are identical when it comes to the diskette drive power interface. All that's left for you to do is wire your breadboard power rails into the four-pin diskette drive power connector's power and ground pins. Depending on

■ **PHOTO 5.** The two-position 0.20 inch pitch screw terminal block is one of many configurations that you can get from Phoenix Contact. This particular interlockable two-position screw terminal block is Phoenix part number 1729128. The screw terminal block is designed to interlock into another like screw terminal block. For instance, you can make a four-position screw terminal block by just using two 1729128 screw terminal blocks.

■ **PHOTO 6.** The four-position diskette drive power connector is something we've been plugging into for years. You can get this power connector and its mating plug from Jameco. The center power receptacle is actually a Type-B USB connector. The business end of a wall wart power cable mates nicely with the industry standard 2.5 mm male power jack.



which of the diskette drive power interface pins you connect, you'll get +12 VDC or +5 VDC. So, be careful. Believe it or not, the Type-B USB connector is 0.1 inch friendly. Two of the USB connector's four pins — which sit on 0.1 inch centers — carry +5 VDC (pin 1) and ground (pin 4). I had to break out the Moto-Tool to mount the 2.5 mm male power jack. This power jack allows you to power your breadboard from the wall wart of your choice.

## How I Do It

There's a breadboard behind every PCB I present in my *Nuts & Volts* and *SERVO Magazine* articles. Needless to say, I've done my share of breadboarding. I use 30 AWG Kynar wirewrap wire to make my breadboard signal connections. The Kynar insulation is easily deformed by the direct heat of a hot soldering iron. Thus, it is possible to accidentally overheat it and compromise the wire's insulation by creating a void. It's uncanny, but those insulation voids always seem to create shorts to nearby exposed connections on my breadboards. If things on your breadboard are squirrely and you can't find a logical reason why, check for wires that are stuck together or stuck to a neighboring solder connection. The insulation voids usually occur at those points.

If the breadboard requires a power and ground bus, I complete the component layout and then route the power and ground busses on the breadboard copper using 22 or 24 AWG tinned copper bus bar.

Working smart also includes being smart when it

comes to tool selection. I consistently use the following breadboarding tools:

- PanaVise Electronic Work Center with 315 Circuit Board Holder
- Variable Speed Dremel Moto-Tool
- Metcal MX-5005 Soldering/Rework System
- Crescent Hand Tools (Home Depot)

Over the years, I've developed breadboarding methods and habits that work well for me. As time passes and you do more and more breadboarding, you will benefit from your experiences, as well.

By the way, if you're having trouble finding that FR-4 plated through-hole breadboard I've been talking about in the catalogs, stop looking. I've supplied a downloadable ExpressPCB file that will allow you to make one (or a few) of your own ([www.nutsvolts.com](http://www.nutsvolts.com)). See you later ... I've got some breadboarding I have to do. **NV**

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## Integrated Ideas & Technologies, Inc., Expands to New Facility



Integrated Ideas & Technologies, Inc., has completed construction and began occupancy of a new 23,000 sq ft manufacturing facility. The new building is located in Post Falls, ID, just eight miles west of their previous facility in Coeur D'Alene.

"We were at maximum capacity in our previous facility and did not have the space for the new equipment required for advancement of both our SMT stencil division and our metal fabrication division," says Michael Ray, President and owner of IIT, Inc. Ray expects the new facility to allow for a 50% increase in production capabilities over the next two years.

## Onwards and Upwards – Radiometrix lends hand to US students

Wireless communication specialist Radiometrix ([www.radiometrix.com](http://www.radiometrix.com)) has supplied two custom radio transceivers to Idaho State University for its Research Involving Student Engineers (RISE) program. The London-based company supplied the pair of customized UHX1 multi-channel radio transceivers tuned to a special VHF frequency (147 MHz) through US distributor, Lemos International ([www.lemosint.com](http://www.lemosint.com)).



The program is sponsored by NASA and releases weather balloons with ceilings exceeding 25,000 meters. The balloons have payloads made up of a camera box, an automatic position reporting system for tracking purposes, and a flight computer. In addition, the balloons can carry various experiments from extremeophile bacteria research to simple egg drop mechanisms.

Weight is a key concern to comply with the Federal Aviation Administration's 12 lb weight limit on these flights. "Finding a compact, light-weight radio solution was vital to the continued success of the project," noted Professor Tim Frazier, the project's faculty sponsor. Researchers have been looking at how to miniaturize the multi-channel tracking package, and the Radiometrix module offered a way of achieving this. "Lemos and Radiometrix have worked with us to choose a suitable transceiver and associated electronics for the project," explained Ben Estes, program member. "The UHX-1 module from Radiometrix has enabled a transparent serial link between the control station and the flight computer in the balloon once it is airborne. This allows full communication between the balloon and the ground crew, allowing them to operate vents, cut-down mechanisms, parachute deployment, and actuate any other mechanisms needed," Estes concluded.

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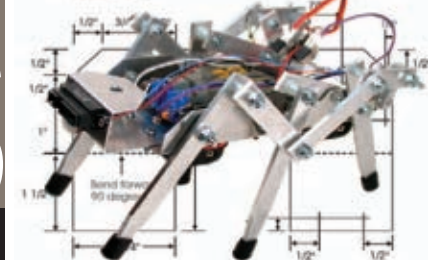
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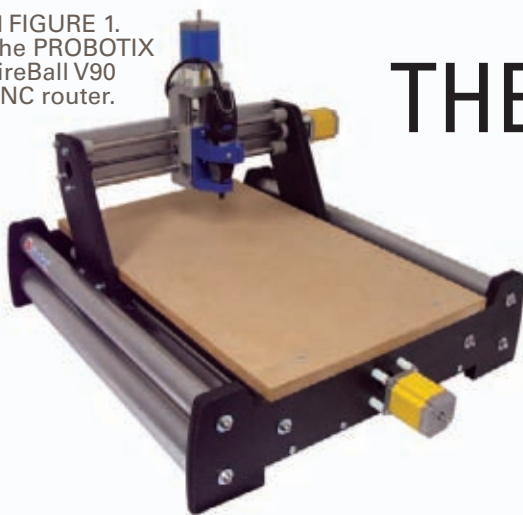
# PERSONAL ROBOTICS

UNDERSTANDING, DESIGNING & CONSTRUCTING ROBOTS & ROBOTIC SYSTEMS



■ BY VERN GRANER

■ FIGURE 1.  
The PROBOTIX  
FireBall V90  
CNC router.



## THE PROBOTIX FIREBALL V90 CNC ROUTER

IN THIS MONTH'S ISSUE, WE CONSTRUCT THE PROBOTIX FireBall V90 CNC router from a kit and then put it through its paces.

### TEA. EARL GREY. HOT.

Jean Luc Picard of *Star Trek* fame had high tech replication gadgets at his disposal. In his Utopian sci-fi future, these devices would be so common that they were used for such mundane tasks as making a cup of tea in the captain's quarters. Although we have a long way to go before we can expect any item we ask for to pop into existence from a wall-mounted gadget, some intrepid folks are diligently working in that direction, starting with automating the creation of parts.

When building things both robotic and mundane, I've found myself sanding, cutting, shaping, bending, and otherwise changing the physical shape of some item used in a project. In many cases, creating exact duplicates of a part is critical to making something that balances or requires matching or aligned holes. Creating these things by hand can be rather time-consuming. It sure would be nice if I could just draw what I needed and then have a device that would cut the part for me. Though not exactly up to the "replicator" on *Star Trek*, if automatic part-making sounds interesting to you, then a CNC machine is a pretty good place to start.

### I SEE, CNC!

CNC or Computer Numeric Control is an acronym that refers to a tool that can cut or shape by using computer generated instructions (see the sidebar for a bit of history). Most CNC machines have a number of axes and a tool of some sort that can be guided by a computer to very precisely remove material. Originally created in the 1940s for the automation of large-scale manufacturing (Figure 2), CNC has become more capable over the years and has made its way down to small desk top fabrication systems. Though some small-project CNC systems are available to the hobbyist, most are in the multi-thousand dollar range so they haven't seen much widespread adoption in the humble homebrew market. Until someone can get the price down to sub-thousand dollar levels, we probably aren't going to see

many of these tools on a typical hobby workbench.

### BRINGING DOWN THE PRICE

I was having lunch with long-time Robot Group member and good friend Paul Atkinson at Pok-e-Jo's BBQ restaurant here in Austin, TX where we were munching BBQ and talking tech while the electric train circled the dining room (see *The TrainSaver, Nuts & Volts*, July '06). Paul mentioned that he had recently read about a new CNC machine from PROBOTIX that seemed to have finally managed to break the \$1,000

■ FIGURE 2. A CNC turning center in the FAME Lab in the Leonhard Building at Penn State. (c) 2005 Nathaniel C. Sheetz.





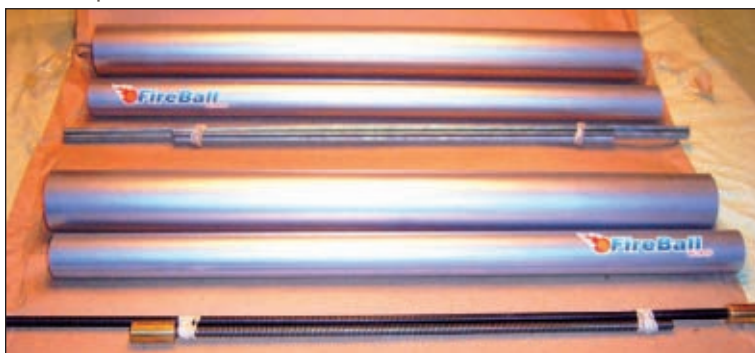


■ FIGURE 3. The 56 pound shipping box from PROBOTIX.

hobbyist CNC router. A bit of investigation showed PROBOTIX offered the FireBall V90 CNC router for \$599 plus another \$309 for an entry-level motor kit that included the stepper motors, the power supply, and the motor controllers. Add in shipping, and you can have a complete CNC router kit on your doorstep for less than a kilo-buck! All you have to provide is the home computer (with a parallel port) to run the software and a Dremel® moto-tool to use for cutting.

I sent an initial inquiry to John Hansford over at FireBall CNC to get some information on the availability of the product and to see if they would be interested in having their CNC router covered in *Nuts & Volts*. John seemed excited about the prospect and put me in touch with Len Shelton over at PROBOTIX. Before I knew it, Len had my order finalized and just a few days later I had one big (heavy) box on my doorstep. Looks like it was time for me to dip a toe into the waters of CNC fabrication, but first I had

■ FIGURE 5. Painted support tubes containing Acme lead screws (with brass couplers) and threaded tension rods (top).



to build the machine itself.

## IT'S HERE!

Amazingly, I received the Fireball CNC in a single box (Figure 3). It weighed in at 56 pounds and was extremely well packed (seemed like the person who did the packing must be pretty good at Tetris!). Overall, the box measured 27" by 16.5" by 8.5" leaving me wondering how they could fit everything in there. I checked the packing list/invoice and it appeared that everything was on the list.

Inside I found two smaller boxes and lots of things wrapped up in brown paper (Figure 4). It still didn't look like there were enough pieces to build a machine but, by the time I finished unwrapping everything, the parts were all accounted for. When I said everything was well packed, I wasn't kidding!

I found that the large side tubes contained the smaller side tubes which contained the lead screws and motor couplers and the threaded frame tension rods (Figure 5). Not only was this a nice use of space, but it was also a very effective way to



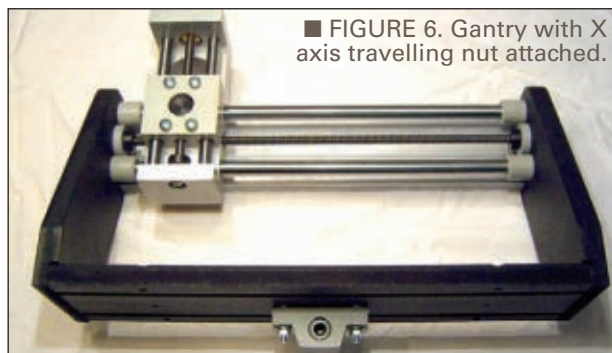
■ FIGURE 4. Nested packages inside the shipping box.

protect the delicate parts while in transit.

After carefully emptying the large box and laying out all the components on the kitchen table, I went to both the Fireball CNC and PROBOTIX websites to look for instructions or pictures to help me with the assembly. I identified all of the major parts and located a couple of tools to help in the process. The primary tools were a 7/16 inch nut driver, a Phillips screwdriver, and a set of Allen wrenches (hex keys).

After identifying the major parts, I cleaned the protective wax from the precision ground and hardened Thomson shaft with some acetone. I then installed the smallest set of rods transverse to the Z axis. I installed the Z axis and rods between the gantry uprights and added the gantry back and base. Next, I added the X drive nut to the bottom of the gantry base. This was starting to look like a CNC machine already (Figure 6).

The next step requires a couple of magazines to hold the frame end plate off the work surface (Figure 7). The frame is assembled vertically to



■ FIGURE 6. Gantry with X axis travelling nut attached.



make it easier to install the threaded rods which tension the frame ends and hold the base together. The magazines provide clearance for the nuts on the end of the threaded rods. The holes that these threaded rods go into are surrounded by a slightly cone shaped recess which helps to guide the rods into and through the appropriate holes.

The precision-ground shafts are put into the gray bushings and the end tubes are put in place. The bushing plates that later connect to the gantry base are added next. (Make sure you install these the right way around as it is tedious to turn them around later.) Finally, the other frame end plate is added and held in place with washers and nuts added loosely (Figure 8).

At this point, the frame can be put flat on the work surface and the gantry is loosely bolted to the gantry bushing plates. Alignment of the unit takes place at this point (before the lead screws are added). By moving the gantry and Z axis assembly back and forth with a finger while carefully snugging up the existing bolts, you can tell if things are in alignment by how easily things slide on the Thomson shafts. Once you have the alignment feeling right, you can tighten the bolts about a half turn past finger tight.

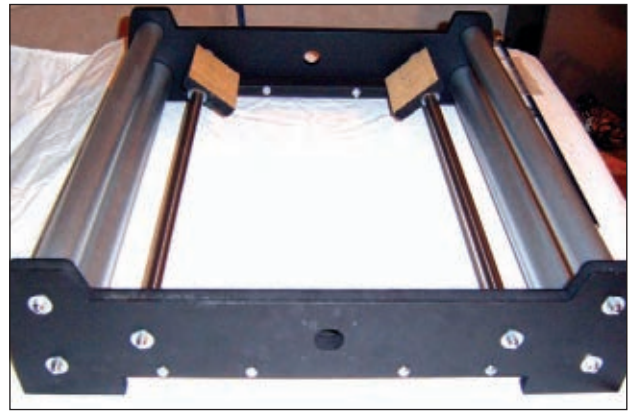
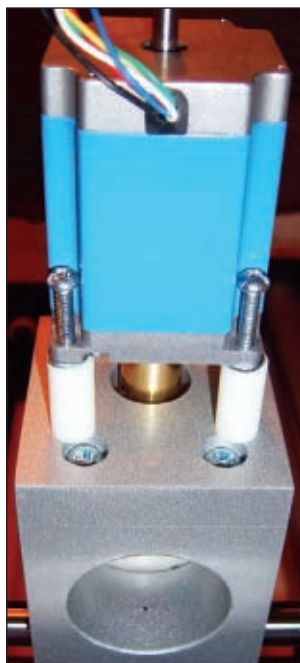
Now that we have the table done, it's time to add the lead screws that the motors will use to control the motions. There are several washers and locking collars which were in small, well labeled bags

■ FIGURE 11. Z axis motor in place — ready to tighten screws.

(Figure 9). It is important to put these parts on in the correct order. (Note: *The Z axis assembly already has its rods and lead screw installed, so we are only dealing with the X and Y axis here.*) Once the lead screws are installed, I again turned them by hand to make sure there was no binding anywhere across the range of motion for both the X and Y axes.

## AND NOW, FOR SOME ELECTRONICS!

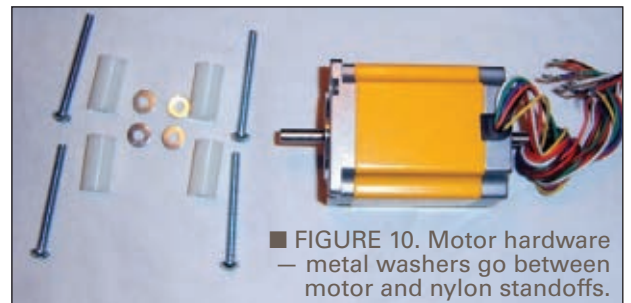
At this point, the complete \$599 FireBall V90 CNC router is assembled. It's now time to move on to the electronics package. In the standard motor package, the



■ FIGURE 8. Front support attached to tension rods (inside silver tubes) via acorn nuts and washers.

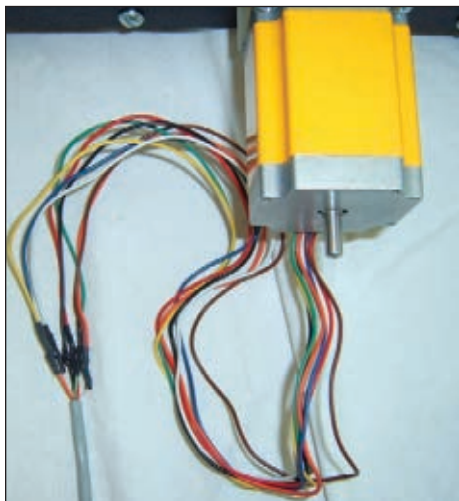
blue motor goes on the Z axis and the yellow motors go on the X and Y axes. Someone was thinking ahead when they thought of color-coding the motors! A quick tip: Before mounting the motors, you may want to consider grinding a flat on the shafts. This will allow the coupler set-screws to make a better seat.

■ FIGURE 9. Starting at top center and going clockwise: table supports, tool holder, Z axis assembly, hookup wire, fuses, fuse holders, power cord, lead screw bearings and clamps, and assorted bags of hardware.



■ FIGURE 10. Motor hardware — metal washers go between motor and nylon standoffs.

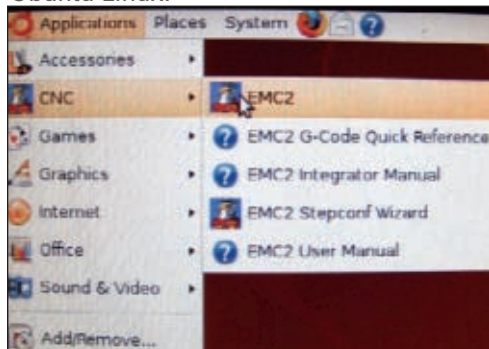




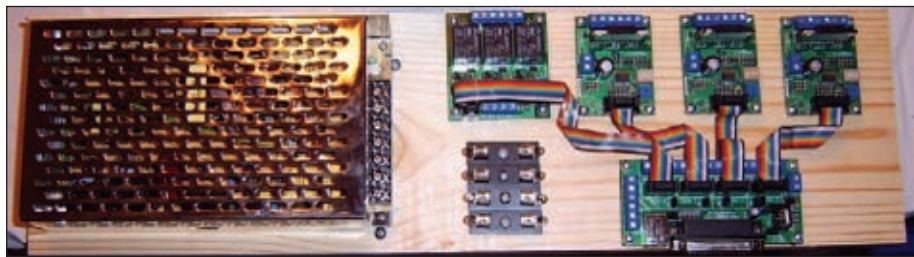
■ FIGURE 12. Stepper leads attached to cable with solder and heat shrink. I did this slightly different than PROBOTIX since I used orange and shield as V+ conductors (they only use orange in the gray cable).

The motors are mounted using nylon stand-offs (Figure 10), and bolted to the top of the Z assembly (Figure 11) and to the gantry or frame side members. I followed the illustrations in the instruction manual and mounted the motors in the standard locations. (Some have asked

■ FIGURE 14. Starting up EMC2 on Ubuntu Linux.



■ FIGURE 15. Mach3 Software up and running on Windows.



■ FIGURE 13. 24V Power supply, relay board, three motor drivers, and breakout board mounted with fuse holders.

if the motor can be mounted on the back of the frame and John Hansford has verified that it is possible to do so, if you prefer.) While working with the machine, I realized that even with the motor wires disconnected, the motors can be hard to turn. I added some knobs (RadioShack part number 274-407) to the back shaft of each motor so I could easily turn the shafts for manual zeroing and to save my fingers! Wiring the motors was surprisingly straight forward. The only trick was realizing that several of the wires go to the positive motor supply and can be connected together to one wire in the cable (Figure 12). Make sure you leave enough cable length appropriate for each axis since they all have different travel

distances. I mounted the motor drivers, relay board, and breakout board on a piece of wood that was large enough to also hold the power supply (Figure 13).

## HARD PART'S DONE, TIME FOR SOME SOFTWARE!

I had help from another

good friend, Robot Group member and Linux expert James Delaney in getting the Ubuntu Linux distribution, EMC2 and Inkscape software up and running on my desktop PC (Figure 14). After playing with the software for a bit, I posted a question to the FireBall forum asking questions about Inkscape (a GNU/open-source design software I was trying). I detailed how I had encountered some difficulty with the apparent lack of an integrated software solution for both the design and tool-path planning end of things. I had a look around at the commercial offerings and, after reading some suggestions on the forum, downloaded a trial version of Mach3, an advanced CNC control application (Figure 15).

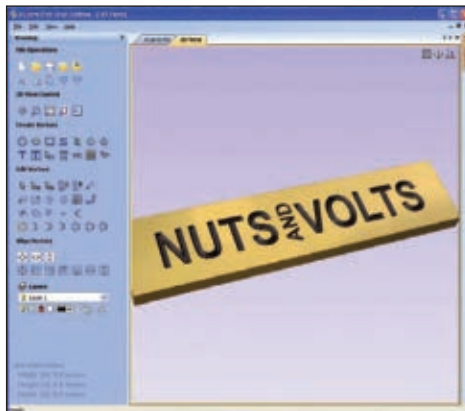
Meanwhile, John Hansford answered my posting (he's quite active in the forum) saying he encountered similar issues and suggested a software package from Vectric called Vcarve Pro. I downloaded the trial version of the software that allows you to try out the design aspect and then cut the example files on your CNC (Figure 16). John spoke with Tony McKenzie at Vectric and arranged for a full copy of VCarve Pro to be sent out to help speed our preparations for Maker Faire (thanks Tony and

Vectric!). I used VCarve Pro to import several bit mapped images and perform the tool path planning for our Maker Faire give-aways (Figure 17).

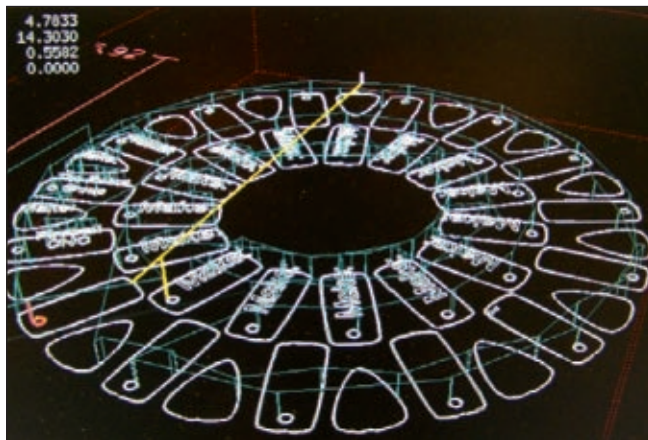
I think it's pretty amazing that there are so many choices for for small-scale CNC software including both GNU/open-source, as well as commercial applications.

My final approach was a

■ FIGURE 16. VCarve Pro with example artwork.



■ FIGURE 17. First layout for CNC cutting keychains for Maker Faire.

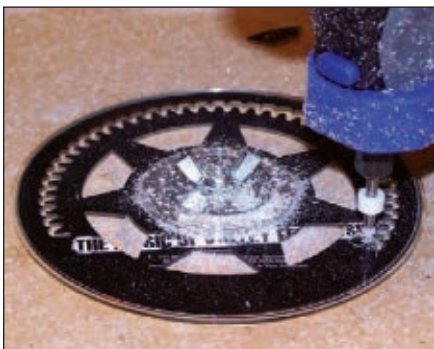


hybrid of all the different packages. For example, my first attempt at running the machine involved manual jogging and running the motor tuning setup within EMC2. I then mounted the standard tool holder which is designed to work with a Dremel model 300 rotary tool and then placed a felt-tip marker in it to test out some drawings. I drew several patterns using the various tools and had success drawing on paper taped to the work surface (Figure 18). By now, I was feeling more confident that I knew what I was doing so it looked like it was finally time to cut something.

## CUT IT OUT, ALREADY!

I installed my trusty old Dremel model 385 Multipro and found it wasn't quite a snug fit. I shimmed it with some thin card stock and was able to use it for cutting in foam. In fact, I even used one of the few pieces of packing foam from the box to carve the sample torus file in EMC2 (Figure 19). Sure was nice of PROBOTIX to provide some test material! Carving foam was fun for a while, but then it was time to find a way to make a sacrificial work surface and come up with a clamping system so we could cut something a bit

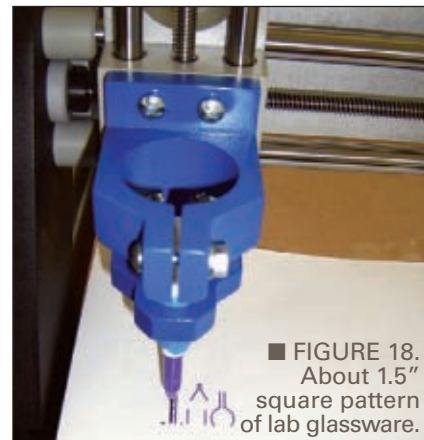
■ FIGURE 20. Custom-machined aluminum shoulder washer holds a CD steady as the Dremel routes a gear pattern.



more substantial than packing foam.

## MAKE: IT HAPPEN!

About this time, Maker Faire Austin was approaching and The Robot Group was preparing a list of projects for the show. As we had a nice new CNC router, we decided to showcase it at the Austin event. We decided the best way to demonstrate the power of the router was to make small give-aways of some type. After toying with cutting shapes out of recycled vinyl LPs (the finished vinyl pieces turned out to be too fragile), we decided on recycled CDs as our media. This required a clamp that



■ FIGURE 18. About 1.5" square pattern of lab glassware.



■ FIGURE 19. First cut of Torus (rough lower edge due to mismatch of cutter and Z depth).

could hold down the CD so it could be held tight while being cut. Again, another Robot Group member came to the rescue. Rick Abbott machined an aluminum shoulder washer that perfectly fit the hole in the center of the CD (Figure 20). That solved my

## HISTORICAL OVERVIEW

CNC was preceded by NC (Numerically Controlled) machines, which were hard wired and their operating parameters could not be changed. NC was developed in the late 1940s and early 1950s by John T. Parsons in collaboration with the MIT Servomechanisms Laboratory. The first CNC systems used NC style hardware, and the computer was used for the tool compensation calculations and sometimes for editing.

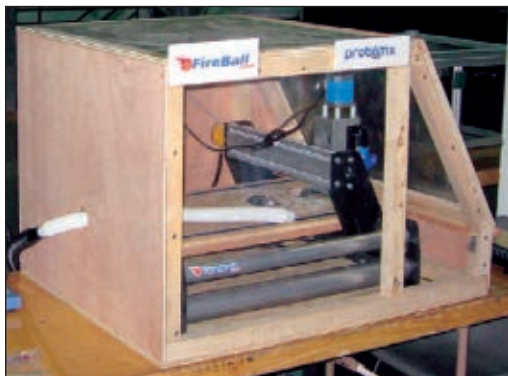
Punched tape continued to be used as a medium for transferring G-codes into the controller for many decades after 1950, until it was eventually superseded by RS-232 cables, then floppy disks, and now is commonly tied directly into plant networks. The files containing the G-codes to be interpreted by the controller are usually saved under the .NC extension. Most shops have their own saving format that matches their ISO certification requirements.

The introduction of CNC machines radically changed the manufacturing industry. Curves are as easy to cut as straight lines, complex 3-D structures are relatively easy to produce, and the number of machining steps that require human action have been dramatically reduced.

With the increased automation of manufacturing processes with CNC machining, considerable improvements in consistency and quality have been achieved with no strain on the operator. CNC automation reduced the frequency of errors and provided CNC operators with time to perform additional tasks. CNC automation also allows for more flexibility in the way parts are held in the manufacturing process and the time required to change the machine to produce different components.

*\*\*From Wikipedia*





■ FIGURE 21. Containment/protection display box created for Maker Faire.

clamping issue, but I had some problems cutting plastic without melting it and soon found out that special cutters and lower cutting speeds are required. Fortunately, Len over at PROBOTIX was willing to do some research on cutting bits and even offered to fly down for the show to provide on-site technical (and moral) support!



■ FIGURE 23. Recycled CDROMs cut into Keychains.

## I (TRULY) GET BY WITH A LITTLE HELP FROM MY FRIENDS ...

Some of you may recall from previous articles how I described The Robot Group here in Austin as my "pallet of talent." The group is a tremendous resource and I have found I can always count on them to step up to the plate in a time of need.

Just after I started on this article, I packed up my house and moved out of Austin to Dripping Springs, TX in preparation for building a new house. The move was more disruptive than I could



■ FIGURE 22. Paul Atkinson (left) and Len Shelton (right) pose with the FireBall V90 at Maker Faire Austin.

As the router would be operated in a public area, I thought it would be a good idea to create a display cabinet to keep noise and debris inside and curious fingers out. I enlisted Wolf Dilworth (yep, another Robot Group member) and Bruce Tabor to help craft a nice wood and Plexiglas cabinet to showcase the CNC machine. The display case was transparent on three sides and incorporated an internal lighting system making it easy to see the router strut its stuff (Figure 21).

The day of the show arrived and Paul Atkinson stepped up to the plate to operate the CNC router with Len Shelton from PROBOTIX at his side for two full days of exhausting, exhilarating Maker Faire fun (Figure 22). Len spent a considerable amount of time tuning the system and sharing his experience with us. He even solved the "cutting bit melting the CD" problem we originally encountered. Len had contacted the

owner of Precise Bits to discuss the results we were getting while cutting CDs. They told us we weren't using an optimal bit and they overnighted the right ones to Len. Turns out a "spiral up-cut bit" was just

the thing for cutting CDs cleanly (thanks Precise Bits!).

After spending some time cutting CDs at the show (Figure 23), we noticed my older model 385 exhibited some run-out (off center rotation) it had developed over the years. The very generous folks in the Dremel booth at the show offered us a free Dremel 300 to use in the router! The new Dremel 300 worked the whole day with hardly any noticeable run-out.

On the second day, after getting comfortable with the V90 using the Dremels, we decided to upgrade to a Porter-Cable trim router that Len had brought with him so he could show the versatility of the V90 with a more powerful tool (Figure 24). Len and John both recommend that you get familiar with the V90 and its capabilities using a Dremel tool before you make this upgrade (and for good reason). Using the Dremel, you can learn a lot while not risking

ever have imagined. Paul Atkinson, Vice President of the group and a good friend, came to my rescue by taking over the CNC mill and build as the move left me with no shop of any kind to work in nor any time in which to work!

In addition to assembling the machine, he took a bunch of great photos (all the assembly photos were courtesy of Paul) and even wrote up extensive notes which account for the bulk of the construction detail in this article. I owe Paul a debt of gratitude and probably a BBQ dinner (or two!) out here in the "country!" Thanks Paul! Couldn't have done it without you buddy!

■ FIGURE 24. Many of the finished pieces created and distributed to folks at Maker Faire Austin.



the damage an “oops” with a more powerful router can cause. In fact, for those of you doing only small or fine work, the Dremel may be all you will need.

The V90 worked perfectly for the entirety of Maker Faire, running continuously over the two days and even winning an Editors Choice ribbon for our display (Figure 25)! In reality, we had more down time with clamping issues and/or working on software designs than anything else. Bottom line is the V90 is a solid piece of gears that can be easily assembled in an hour or two. With the well-matched electronics package, it makes a solid CNC machine that you can use and enjoy for hobby and light commercial use. It stood up to a demanding show schedule without skipping a beat.

It can cut foam, MDF, wood, plastic, fiberglass, light carbon fiber, printed circuit boards, and solid surface (synthetic counter-top) material and we look forward to trying it out on ALL those materials! Though the FireBall's creator has reservations about doing so, some brave souls have even tried working metals with the V90, performing light cuts in aluminum and brass with very good results (check the Resources

■ FIGURE 25. Paul Atkinson shows off the Editors Choice blue ribbon won for the FireBall CNC display at the Faire.



section for the V90 forum where users discuss their experiences). It all comes down to having a solid machine (PROBOTIX and FireBall make that part easy) and the patience to learn.

The PROBOTIX FireBall V90 CNC will be a centerpiece in my workspace for the foreseeable future and, based on the results so far, I think you can expect to see another entire article devoted to using the V90 to create parts a bit more useful for hobby robots than key chains (Figure 26)!

As always, if you have any questions, please feel free to email me at [vern@txis.com](mailto:vern@txis.com).

**NV**

■ FIGURE 26. CD-ROM Gears and Key chains.



I'd like to thank Len Shelton and John Hansford for making the PROBOTIX FireBall V90 CNC a reality and for making a sub-\$1,000 commercially available CNC system a reality. Also, special thanks to Tony McKenzie at Vectric for the VCarve Pro we used at Maker Faire. You guys rock!

I'd also like to thank Paul Atkinson (hardware/photography/electronics), James Delaney (software), Rick Abbott (parts fabrication), Wolf Dilworth and Bruce Tabor (display case construction), and Kym Graner (show coordinator) for their assistance and support!

## RESOURCES

■ PROBOTIX — [www.probotix.com](http://www.probotix.com)

■ FireBall CNC — [www.fireballcnc.com](http://www.fireballcnc.com)

■ PROBOTIX FireBall V90 CNC at Maker Faire Austin 2008 — <http://makerfaire.com/pub/e/2151>

■ FireBall V90 chat forum — <http://groups.yahoo.com/group/Fireballcnc>

■ VCarve Pro — [www.Vectric.com](http://www.Vectric.com)

■ Precise Bits — [www.precisebits.com](http://www.precisebits.com)

■ ArtSoft Mach3 CNC Software — [www.machsupport.com](http://www.machsupport.com)

■ Linux CNC “Enhanced Machine Controller - EMC” — [www.linuxcnc.org](http://www.linuxcnc.org)

■ Dremel Tools — [www.dremel.com](http://www.dremel.com)

■ The Robot Group — [www.TheRobotGroup.org](http://www.TheRobotGroup.org)

■ Pok-e-Jo's BBQ in Austin — [www.pokejos.com](http://www.pokejos.com)

■ The Train Saver — [www.nutsvolts.com/preview.php?issue=11](http://www.nutsvolts.com/preview.php?issue=11)

**FireBall V90**  
Desktop CNC Router Kit

Complete 3-Axis Stepper Motor Driver System

**THE ULTIMATE Dremel Tool Accessory!**

- ▶ 12" x 18" x 3" Tool Travel
- ▶ Thomson Precision Linear Shafts & Oilite Bearings
- ▶ Precision Acme 2-start Leadscrews & Delrin Nuts
- ▶ Solid Brass Machined Couplings
- ▶ Cast & Machined Industrial Grade Z-Axis
- ▶ Tool Holder for Dremel Model 300
- ▶ 220+ Inches Per Minute Rapids
- ▶ Easy To Assemble, Easy To Use

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# PICAXE PRIMER

SHARPENING YOUR TOOLS OF CREATIVITY

■ BY RON HACKETT

## EXPERIMENTING WITH THE IR MULTI-BOARD

**In the previous installment of the Primer, we constructed a stripboard version of the IR Multi-Board, which can implement the full range of PICAXE IR capabilities. We also tested it with a simple program that received and decoded the signals from a Universal TV remote programmed to transmit the Sony IR Control (SIRC) protocol.**

**T**his month, we're going to continue our exploration of PICAXE IR capabilities, which we have divided into three basic categories:

- The transmission and/or reception of IR signals that use the SIRC protocol.
- Object detection using infrared "echoes."

- The wireless transmission and/or reception of standard serial data by modulating and/or demodulating an IR carrier wave.

### IR TRANSMISSION AND RECEPTION OF SIRC SIGNALS

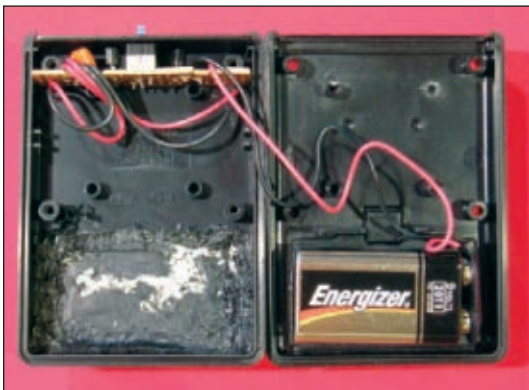
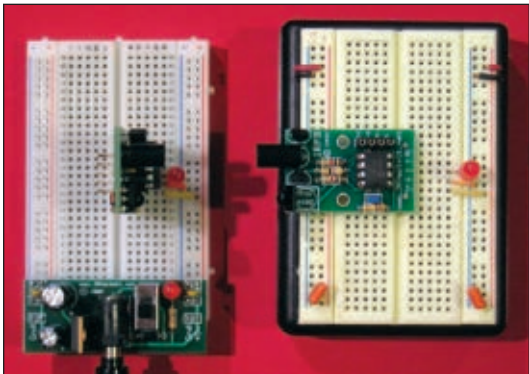
At this point, we have already successfully received SIRC IR signals from a TV remote, so let's turn our attention to the transmission of SIRC signals. In order to do so, we will need to use two IRMB systems — one for transmission and the other for reception. The experimental setup that I used is shown in Figure 1. As you can see, I'm using two of my IRMB printed circuit board (PCB) setups, but any combination of breadboards, stripboards, and/or PCBs will certainly work. You can also see that the transmitting IRMB (on the right of Figure 1) has been assembled to mount horizontally on the breadboard, while the receiving IRMB (on the left) has been assembled to mount vertically. You can easily do the same thing with the stripboard

circuit we constructed last time. If you are interested in doing so, see the IRMB page on my website ([www.JRHackett.net/IRMB.htm](http://www.JRHackett.net/IRMB.htm)).

If you want to do any sort of range testing for your system, it will be helpful to configure your transmitting unit as a battery-powered device. The black project case below the breadboard on the right of Figure 1 contains a nine-volt battery, a simple +5V regulated supply, and an on-off switch that controls power to the breadboard (see Figure 2). The mess in the lower left corner is the result of my having to gouge out that part of the case because the nine-volt battery was a little too large to fit inside and I had already adhered the breadboard to the top of the box. (Plan ahead, I always say!)

You can also accomplish the same thing by simply attaching the battery to the breadboard with a rubber band and wiring the supply components directly on the breadboard. However, if you would like to construct a project case version of the circuit, Figure 3 presents the circuit schematic and Figure 4 presents the stripboard layout I used. There is only one cut needed on the bottom of the circuit board (to separate the two relevant switch contacts), but I haven't shown it because its exact location will depend on the specific switch you use. Also, you may need

■ FIGURE 1. SIRC Tx-Rx setup.



■ FIGURE 2. Interior photo of project box.

to adjust the size of the stripboard to fit your project box.

You may have noticed that I haven't included a circuit diagram for either the IR transmitter or the receiver. That's because all the necessary circuitry is already contained on the IRMB boards. All you need to do is make sure that both IRMB circuits are properly connected to +5V and ground. On the transmitter circuit, you may also want to connect an LED and current-limiting resistor from the 08M output1 to ground. I used it to blink after each transmitted digit just so I knew the circuit was functioning properly. To test your SIRC IR link, type the SIRC transmission program (listed in Figure 5) into the Programming Editor, connect a programming adapter and cable from your PC to the IRMB, and use the Programming Editor to load the program into your battery-powered IRMB transmitter. For the receiver circuit, you can again use the "IRMB\_Remote.bas" program we tested last time (available at [www.nutsvolts.com](http://www.nutsvolts.com)). Don't forget to leave the receiver's cable connected to your PC because the received data will be sent to the Terminal Window. The transmitter program repetitively sends the digits 0 through 8 to the receiver, which serially sends the data on to the Terminal Window. Don't forget, the "IRMB\_Remote" program adds 1 to each received signal to correspond to the digits on the TV remote, so you should see the digits 1 through 9 being received in the Terminal Window.

It's a simple matter to test the range of your system. Just move the portable transmitter a few feet from the receiver (making sure the IR LED is pointed directly at the receiver) and walk back to the PC to see if the correct data is being received. (Of course, if you walk between the two systems you may get some garbled data, but the transmission should correct itself as soon as you get out of the way.) I was easily able to get reliable operation at a distance of 20 feet, which is as far away as I could get in my basement work area.

## USING IR FOR OBJECT DETECTION

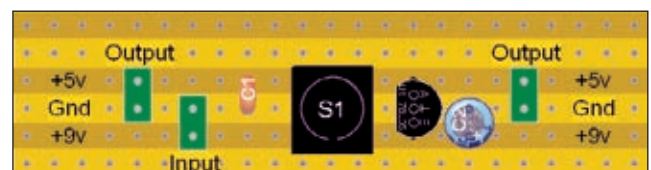
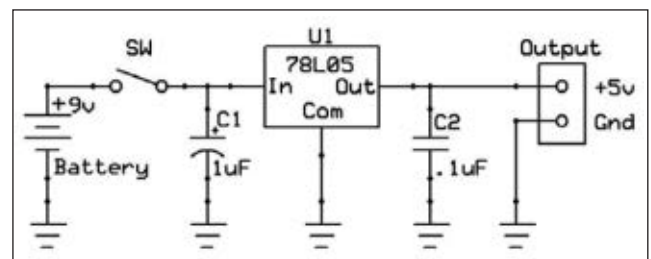
The next PICAXE IR function we'll investigate is obstacle detection. In this case, the same IRMB circuit will implement both the transmission of the IR carrier wave and the detection of an echo that indicates the presence of an obstacle in front of the IRMB. The software (IRMB\_Echo.bas) is too long to include here — you can download it from the *Nuts & Volts* website and open it with the Programming Editor. You can use either a horizontal or a vertical IRMB setup to test the software. Also, be sure you include an LED and current-limiting resistor on output1, because it's used to indicate the presence of an obstacle.

There are a couple of points about the "IRMB\_Echo" program that may require explanation. To begin with, let's examine the process involved. Essentially, the IRMB emits five short bursts of a 42 kHz IR signal and immediately after each burst listens for the presence of an echo. Since the signal is traveling at the speed of light, it's necessary for the 08M to be very fast in making the transition between transmitting and listening.

This is why the program is configured to run at 8 MHz; 4 MHz is just too slow to detect the echo signal. Figure 6 presents a graph of the sensitivity of the PNA4602 verses the frequency of the incoming IR signal. As you can see, the sensitivity decreases as the frequency varies either up or down from the 4602's central frequency of 38 kHz. Considering this, you're probably wondering why I chose 42 kHz rather than 38 kHz for the PWM frequency.

When I first

■ FIGURE 4. 78L05 circuit stripboard layout.



```
; === IRMB_SIRC_Tx.bas =====

; === Declarations =====

symbol index = b0
symbol LED = 1

; === Directives =====

#com1
#picaxe 08M

; === Begin Main Program ===

high 2 ; enable IRMB
; transistor

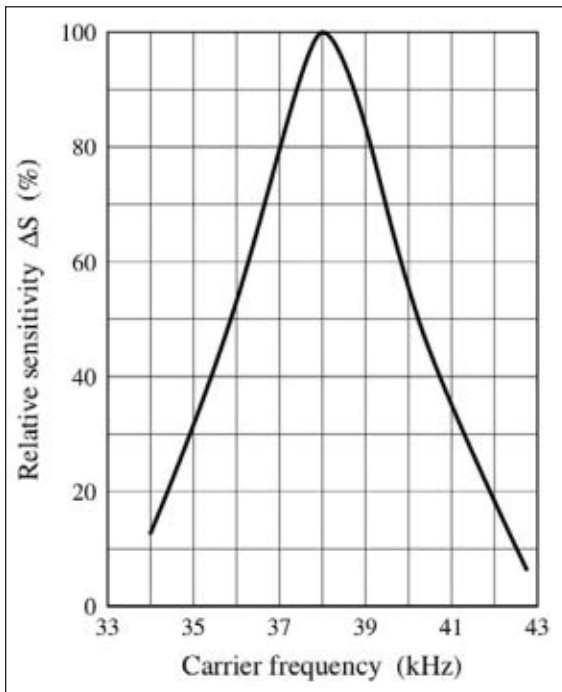
do
  for index = 0 to 8
    high LED
    infraout 1, index
    pause 250
    low LED
    pause 250
  next index
loop
```

■ FIGURE 5. SIRC Tx program.

began development of the program (using only single transmissions), I naturally did choose 38 kHz but my results were plagued with sporadic false positives. The IRMB would frequently report an echo when there was no obstacle anywhere near it. My first thought was that the heat-shrink tubing that shields the sides of the IR LED might be "leaking," so I used a toothpick to apply a small amount of black silicone sealant wherever I thought it would help, especially around the base of the LED on the horizontal version of the IRMB. This did reduce the false echoes somewhat, but it did not eliminate them entirely. At that

■ FIGURE 3. 78L05 circuit schematic.





■ **FIGURE 6. Graph of PNA4602 sensitivity.**

different characteristics, so you may also want to experiment with varying the number of repetitions, as well as detuning the PWM signal more or less than I did. To determine the correct parameters for the PWM command, you could refer to Part II of the manual or just use ProgEdit's "PWM Wizard," located under "PICAXE > Wizard > pwmout" in the menu structure. Don't forget to select the 8 MHz option or your parameters will be entirely off base.

Of course, there are situations in which you might want a range shorter

point, I realized that the high power IR signal produced by the IRMB's driver transistors were, in this case, probably producing the excessive sensitivity I was obtaining. In any case, the dual approach of detuning the PWM signal to 42 kHz and requiring five positive echoes before reporting an obstacle completely corrected the problem. My suggestion would be to experiment with the software approach first — you might be able to avoid the mess of black silicone altogether.

Your IRMBs may have slightly

than four feet. For example, if you wanted to detect whenever someone walks down a hall, the PWM parameters in the program would most likely detect the other side of the hall 100% of the time, rendering the system useless. The solution is to detune the circuit even farther away from the 4602's resonant frequency; if you want a shorter range of detection, just experiment with raising the PWM frequency a little at a time until you obtain the range you want.

You can also shorten the range somewhat by decreasing the duty-cycle. The advantage to this approach is that a duty-cycle below 50% results in the IR LED being powered for a shorter amount of time during each cycle so that a fair amount of power is conserved. Of course, this could be a significant factor in battery-powered systems, so you may want to experiment with changes in the duty cycle, as well.

On the other hand, if you want a range greater than four feet,

you could set up two IRMB systems: one to transmit a 38 kHz IR beacon; and the other to receive it and sound an alarm (or count the passers-by, or whatever) whenever the beacon was broken. Since this approach would not involve echoes, you should be able to get a range of 20 feet or more. Come to think of it, this would make a great homework project. If you implement it, let me know the range you get.

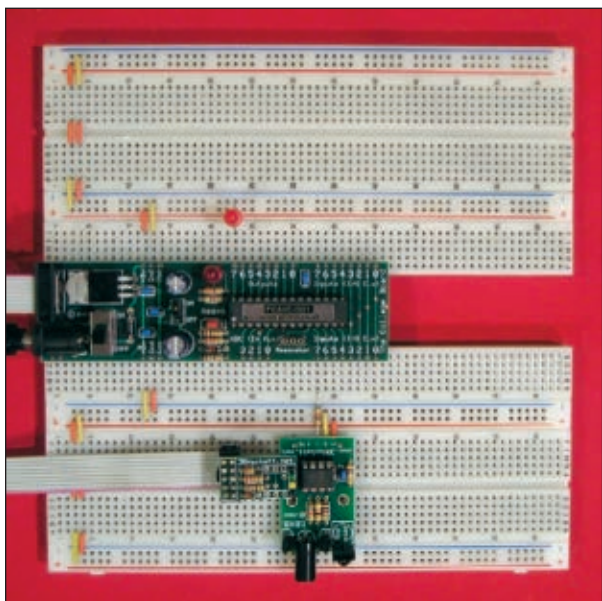
## SENDING SERIAL DATA TO THE MASTER PROCESSOR

Now that we have our IRMBs talking to each other, we're ready to connect one of them as an input peripheral for our 28X1 master processor. Figure 7 is a photo of my master processor setup for the remainder of this installment. As you can see, I'm using the College Board (available at [www.JRHackett.net](http://www.JRHackett.net)) but either the breadboard or the strip-board setup we developed previously will work just as well. To connect the IRMB to the master processor, simply connect output1 of the IRMB to input7 (Ser Rx) of the 28X1. The safest way to do this is to use a 4.7K resistor for the connection. This protects the circuit from the possibility that input7 on the 28X1 is accidentally reconfigured as an output.

If this were to happen and output1 on the 08M happened to be high at the same time that (the reconfigured) output7 on the 28X1 was low, a direct short (and possible damage) would occur. As a general rule, always connect two PICAXE I/O pins using a 4.7K resistor in series to avoid this possibility.

In this setup, we're again going to use the IRMB to receive IR commands from an SIRC TV remote. However, rather than transmitting each received command to the Terminal Window as we did earlier, this time the IRMB will send the received data on to the 28X1 master processor.

To accomplish this task, we can make two simple changes to the



■ **FIGURE 7. 28X1 master processor setup.**

“IRMB\_Remote” program we used earlier. First, remove (or comment out) the “#terminal 4800” directive because the IRMB will be outputting to the master processor, not the Terminal Window. Second, replace the `sertxd` command with “`serout 1, T2400, (infra)`” to send the data to the 28X1 on output1. Notice that we’re not including the “#” in front of `infra` this time. That’s because we now want each key press to be sent as a single byte rather than individual ASCII digits — we’ll see why when we discuss the 28X1 software. Save the modified program (with a suitable name) and download it to your IRMB circuit.

## RECEIVING SERIAL DATA IN THE BACKGROUND

Before we get into the specifics of the serial input program, we need to first take a look at how serial data reception is implemented in the background on the 28X1 (and 40X1). As usual, it’s a good idea to read through the relevant documentation in Part II of the manual (see the “`hsersetup`” command). The first time you encounter this material you may feel slightly overwhelmed by the apparent complexity of what’s involved. However, we’re going to implement one of the less complex ways of accomplishing our goal so by the time you finish this section, hopefully it won’t seem so difficult.

`Hsersetup`’s full syntax is “`hsersetup baud_setup, mode`” — “`baud_setup`” refers to the serial baud rate configuration and “`mode`” is a two-bit parameter that we’ll clarify momentarily. The specific command that we’ll be using in our program is “`hsersetup B2400_4, %01`” and it requires some explanation. Let’s consider the “`baud_setup`” parameter first. Our IRMB program is transmitting at 2400 baud, so we need the same baud rate on the receiving end. If you have used the `serout` command, you are probably familiar with the distinction between “T2400” and “N2400” baud

rates. Without getting into too much detail, you generally want to use a true output (T) if you are dealing with level shifters (such as the MAX232) and PCs; an inverted output (N) is required if you are communicating between two PICAXEs or peripherals such as LCDs. However, the 28X1’s “`hserin`” input only accepts true serial inputs so, in this case, we don’t have a choice; which is why the IRMB’s serial output is set to true. The B in the “`baud_setup`” parameter just takes the place of T or N since it can’t be changed anyway. At first glance, the “\_4” may seem a little confusing. However, it’s actually a simplification. In earlier versions of the PICAXE software, if you changed the system clock from the 4 MHz default, baud rates (among other things) were affected.

For example, if you specified the N2400 baud but ran the processor at 8 MHz, you would actually get N4800 because you doubled the clock speed. It was surprisingly easy to forget this (at least for me!) and end up wondering why the program didn’t communicate serially. With the latest revision of the software, you can use “N2400\_8” to specify that you want 2400 baud even though you’re running at 8 MHz, which is definitely an improvement in the syntax. That explains the “`hsersetup`” command’s “`baud_setup`” parameter so let’s move on to the two-bit “`mode`” parameter. Bit1 of “`mode`” controls the polarity of the “`hserout`” signal (which can be changed: 0 = true and 1 = inverted). However, we aren’t using “`hserout`,” only “`hserin`” and, as we mentioned above, the “`hserin`” signal must be true so we need a 0 in bit1. Bit0 of “`mode`” controls how the serial input occurs.

A 0 in this position means that we intend to actually use the “`hserin`” command to fetch the data, and a 1 in the bit0 position means that we want the serial reception to occur automatically in the background (no “`hserin`” command in the program), regardless of what our program happens to be doing when the data arrives. This is exactly what we want to do, so we need a 1 in bit0, result-

ing in the “`hsersetup B2400_4, %01`” command we specified earlier. By now, you’re probably wondering what happens to the serial data that is being received in the background — the answer is that it’s automatically placed in a special part of the 28X1’s memory called the scratchpad (see the section entitled “Variables – Scratchpad” in Part II of the manual). The 28X1 has 128 bytes of scratchpad memory for temporary data storage, which can be accessed by two new commands: “`put`” and “`get`.” We’ll focus on “`get`” right now because that’s the one we’ll be using.

In its simplest form, the syntax is “`get location, variable`” where “`location`” refers to a specific address (0 to 127) in the scratchpad, and “`variable`” is the name of the variable that receives the data byte from the scratchpad location specified.

## SERIAL INPUT SOFTWARE FOR THE 28X1

The 28X1 software we’ll use to implement serial data reception in the background is a little too long to manually type into the Programming Editor. Rather than present it here, it’s also available on the N&V website. Download the “`HserinTest.bas`” file, open it with the Programming Editor, and print a copy for reference during the following discussion.

Because the process of receiving serial data in the background can get complicated, our first attempt will implement a simple goal. At the same time that the 28X1 is busy doing other things (in this case, just blinking an LED), it receives the incoming data from the TV remote in the background. After each blink of the LED, the program checks to see if serial data has been received during the blink and, if so, transmits it to the Terminal Window on the PC. Since it takes a full two seconds for a single blink to transpire, it’s easy to press two or more buttons on the remote during that time interval.

In order to keep this first example as simple as possible, only



the first key press during each blink will actually make it to the Terminal Window; the others will be lost. In the next installment of the Primer, we'll make the necessary modifications to capture all the data that is sent, but for now we'll focus on our simplified example.

If you read through your printout for the "HserinTest" program, you can see that it's fairly thoroughly commented. However, there is one

important aspect of the program that I didn't have space to explain in the comments, so let's discuss that now. The PICAXE system has three built-in variables for use with background serial reception:

- **Hserinflag** is a flag that indicates that new data has arrived in the background. It is initially reset to 0 and as soon as a background serial receive has occurred, the system

automatically sets it to 1. Your program can then test hserinflag to check whether there is data available in the scratchpad — that's the function of the "if" statement block in the program.

- **Hserptr** points to the location in the scratchpad in which the next received data byte will be written. Pointers are a powerful way of accessing and manipulating data, but the details can get complicated.
- **Ptr** points to a location in the scratchpad from which we can access (read) a received data byte. (We'll discuss the use of pointers in the next installment of the Primer.) To keep things simple, we'll avoid using the built-in pointers and simply access the data in the scratchpad location 0.

Each time the data has been accessed and sent to the Terminal Window, the built-in variables must be reset. We'll get into the reasons and details next time. For now, we'll just use the "ResetAll" subroutine for that purpose. If you haven't already done so, use the Programming Editor to download the modified "IRMB\_Remote" program (the one you renamed and saved earlier) to your IRMB circuit and download "HserinTest.bas" to your 28X1 circuit. Be sure to leave your programming adapter and cable connected between the 28X1 and your PC so you can view the received data in the Terminal Window. Point your SIRC TV remote at the IRMB and press a key. You should see a data byte appear in the Terminal Window. Remember, there will most likely be a delay of a second or more while the 28X1 is busy blinking its LED.

Experiment with pressing multiple keys during a single blink. You'll see only the first key press will show up. Next time, we'll modify our program so that it can capture and display every key press we make. If you like a challenge, study the relevant documentation in the PICAXE manual and see if you can make the necessary changes before we discuss them here. See you then. **NV**

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## SIX THINGS YOU SHOULD KNOW ABOUT WIRELESS

**YOU ALL KNOW HOW MUCH WIRELESS HAS INFLUENCED YOUR LIFE IN THE PAST YEARS.** If you haven't thought of that, you should stop a minute and just list the wireless things you use everyday. Your cell phone, wireless laptop, your FM or AM radio, TV set, or the remote keyless entry on your car are just a few examples you tend to take for granted.

**W**ireless started changing the world just after it was invented by guys like Marconi, Tesla, and others in the late 19th and early 20th centuries. And that change is still going on. Here are a few wireless developments maybe you didn't know about.

### HAPPY BIRTHDAY CELL PHONES

This year marks the 25th anniversary of the cell phone. Is it older than you thought? I didn't realize it had been that long. What an impact the cell phone has had on our lives! The first cellular call was made in Chicago in 1983. It was from a big car phone which was the first real cellular product. The "handhelds," which came later, were rightly referred to as "bricks." They were large and heavy (2-3 pounds) and looked more like military walkie-talkies, costing \$3,000-\$4,000 each. They did work and word got around. It was one of the few products of the early '90s that people actually lusted after for the cool factor alone. It took years to cram all that circuitry into the small, pocket-sized cell phones we have now.

After years of semiconductor chip progress, the number of chips in a handset has decreased from a dozen or so to just a few. Not only that, these phones are more reliable on voice calls and we can also send text messages and email, take photos with the internal digital camera, receive videos, and even link to Wi-Fi wireless LAN hot spots where available. These so-called smart phones are getting better each year and as prices drop, more and more people are trading their older voice-only phones in.

The popularity of the BlackBerry, Apple iPhone, and the new LG G1 with Google's Android operating system highlights this trend.

Increased cell phone handset sales are projected despite the near saturation rate in the US, Europe, and parts of Asia. Families now routinely have two or more cell phones.

### TURNING OFF ANALOG TV

In case you haven't heard yet, the FCC (Federal Communications Commission) has mandated the shut-down of analog TV transmissions. Future TV broadcasts will be in digital

and most in high definition (HD). The date for the switchover is February 17, 2009. What that means to you is that if you currently still get your TV over the air, as of that date, you won't get it any more. You will need a new digital TV set to get the same stations (but on a different channel).

Over 80% of US citizens get their TV via cable or satellite, so if you do, that change-over will not affect you. Your cable or satellite provider accommodates everything for you. You can even keep your old analog TV set, if you wish. If you are one who still gets your TV with an outdoor antenna or rabbit ears, then you will need to get a new digital TV or at least get one of the many converter boxes now on sale.

Your friendly US government set aside a bundle of cash to subsidize these boxes that convert the received digital TV signals into an analog signal you can get on your old analog set. You actually can get two \$40 rebate cards to help cover the costs. These boxes are available at stores like Best Buy, Circuit City, and Radio Shack to name a few. Go to the National Telecommunications and Information Administration's (NTIA) website at [www.ntia.doc.gov/dtvcoupon/](http://www.ntia.doc.gov/dtvcoupon/) and sign up. More

information on the switch-over is there, as well.

When the analog to digital switch-over occurs, your local stations will move to different channels, most likely from VHF to UHF. If you don't know how to find the new channel, you can go to the FCC's website ([www.transmitter.com/FCC98315/chanplan.html](http://www.transmitter.com/FCC98315/chanplan.html)) and get details there. One quick comment on antennas. If your rabbit ears get both VHF channels (2-13) and UHF channels (14-59), you will be okay. Same with an outdoor or attic combo VHF/UHF antenna. Remember, higher frequencies travel shorter distances than lower frequencies for the same power. So, your stations new UHF signals could be lower in level with the new digital TV. A higher gain antenna will make up the difference.

With digital signals, there is no gradual weakening as indicated by "snow." What you will get is a pixilated screen and then nothing if you are out of range.

## M2M ON THE RISE

What the devil is M2M, you ask? It stands for machine-to-machine. It is a growing technology that extends the use of a cell phone system to other than personal human to human voice and text communications. Instead, it implements communications between machines — machines talking to other machines or humans talking to machines. Sounds a bit eery at first but as it turns out, it is an amazing additional use of the large and very expensive cell phone infrastructure made up of over 260,000 base stations in the US alone. Here's how M2M works. It is a form of wireless telemetry and control. Telemetry is the old term that means measurement at a distance — usually by wireless. Suppose you want to watch the temperature of a pipeline miles away from you or even across the country. You install a temperature sensor on the pipe and send the electrical signal to a cell phone. The cell phone is basically just the radio without the keyboard, display, speaker,

■ **FIGURE 1.** This GSM/GPRS M2M cell phone modules by Telit Wireless Solutions is only 1.7 x 1.7 inches square and operates in the standard 850/900/1,800/1,900 MHz cell phone bands. It can send short text messages or audio. This model has a built-in GPS receiver so it can report its location to the caller.

and microphone. It sends the digital version of the temperature over the cellular network to your phone or computer.

Suppose you want to control the liquid level in a remote tank. You could monitor the level with a sensor, then use that indication to turn a pump on or off to refill the tank when necessary. Could all be miles or a continent away.

M2M is the ultimate long range remote control. As long as you can get through a cellular network, you can monitor or control anything from any place at anytime. M2M has been around a few years and growing silently. Tiny cellular radios in modular form are cheap and widely available to enable almost any conceivable remote monitor or control function at a very reasonable price.

Vending machine companies use M2M to alert them that a machine needs refilling or maintenance. Trucking companies routinely use it to track their trucks and payloads. Companies attach an M2M transceiver on a high value asset like a bulldozer or large crane and monitor its presence or condition by a simple phone call. You can even put a video camera on one of the transceivers and keep an eye on your home while you are on vacation. Just call in and take a look at the current video conditions. Figure 1 shows a typical M2M cell phone module.

M2M is an impressive extension of the cellular system. With cell phone saturation nearing 50% of the



world population of just over 6.5 billion folks, where does one go for growth? The answer is M2M. Some companies have estimated that there could be between 50 or 60 billion devices, machines, or things that ought to be monitored, tracked, or controlled. M2M is cheap and easy, so look for more of this "invisible" technology.

## WHITE SPACES IN YOUR FUTURE

Another hot topic these days in wireless is "white space." This is the term for those TV channels that will become vacant during the switch-over from analog to digital or those TV channels essentially unused or unassigned. With spectrum so limited and expensive, many are wondering why all that precious TV spectrum will go unused. Why not put it to work in cellular or other forms of wireless like high speed Internet connections or wireless networks? Most of it is in the highly valued VHF spectrum where signals travel far, penetrate walls, and allow many new useful services to be implemented.

By using smart technology, a radio will be able to monitor the spectrum for potential interference before transmitting and then decide not to transmit or to change frequencies.

The FCC recently issued a



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statement saying that it would consider new services in the white spaces as long as they do not interfere with other nearby existing wireless services. TV broadcasters have really fought against that, but so have the wireless microphone manufacturers and users. They claim their low power microphones will be widely interfered with. Tests by the FCC, however, say this isn't so.

## 60 GHz — THE WIRELESS FRONTIER

When you start running out of spectrum space, you start looking for more spectrum. However, keep in mind that spectrum is like land: There is only so much of it to go around. The spectrum is owned mainly by countries and a handful of large companies. We've used up just about all of it.

One solution would be to make better use of what you have. For radio, that means sharing frequencies and/or using clever modulation and multiplexing techniques. TDMA, CDMA, and OFDM already make it possible for cell phone operators to squeeze more subscribers per Hz of spectrum space than ever before.

There is spectrum available in the 30 to 300 GHz range — super the extremely high frequencies. In fact, these are so high they're only a bit below the infrared (IR) optical spectrum. This wavelength is so small, it is commonly referred to as millimeter (mm) waves. The problem with using these frequencies is that it is very difficult to make electronic components work at these frequencies. Current semiconductor technologies are now allowing radios to be made. One other downside is that such waves are easily scattered and won't penetrate walls. Existing applications are in mostly military radar and satellites, but also in some short-range backhaul for networks and cellular systems.

There is also an unlicensed band open for use in the 57 to 64 GHz range. Some have already targeted 60 GHz as a band where very high

speed digital data can be transmitted at rates of up to about 10 Gbits/second. One application already available is called WirelessHD: a wireless technology that lets you transmit uncompressed, high definition TV (1.5 to 3 Gb/s depending on level of definition) over several meters.

## WIMAX NOW OUT THERE

WiMAX, of course, is the high speed wireless metropolitan area network (MAN) technology that was created to compete with DSL and cable TV Internet access. It uses OFDM in the 2.3 to 2.5 GHz bands in the US, and 3.5 GHz in Europe and other parts of the world. For people in remote and rural areas without Internet access services, WiMAX provides a high speed connection (> 1 Mb/s) to the Internet for anyone within range of a basestation. WiMAX is widely deployed outside the US for telephone service (Voice over IP), as well as Internet connectivity. Adoption of it has lagged in this country mainly because companies have struggled with business models, as well as technical problems. Now, Sprint Nextel has launched its first commercial WiMAX service in Baltimore. Called XOHM, this service is expected to roll out over the US as Sprint and wireless innovator Clearwire build out a nationwide system. It is a fourth generation (4G) technology that could eventually include voice service that is in direct competition with existing wireless operators. There are no WiMAX cell phones yet, but you can get WiMAX USB dongles, PC cards, and modems for home and office use. Intel has chips that will put WiMAX into laptops in the near future. With this service and no fixed contract, you get high speed Internet connectivity that easily competes with Wi-Fi hot spots, as well as some 3G cell phone data services. Look for XOHM in Chicago and Washington, DC soon. Go to the Sprint XOHM website for details. **NV**

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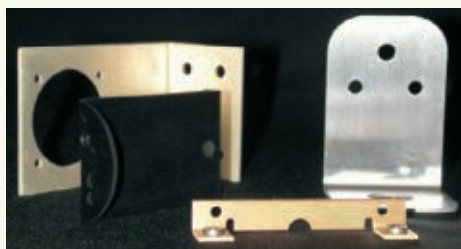
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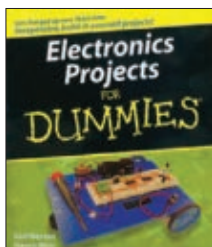
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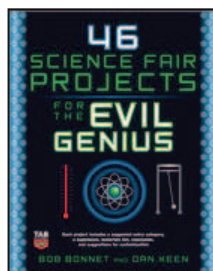
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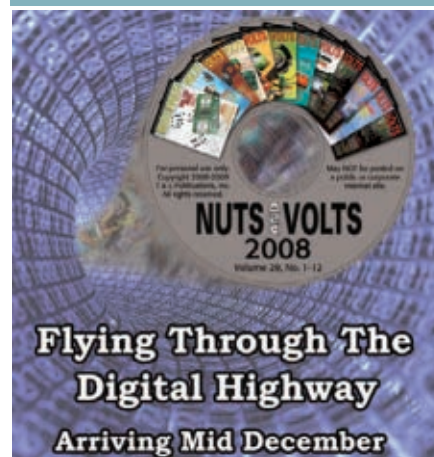


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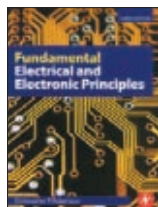
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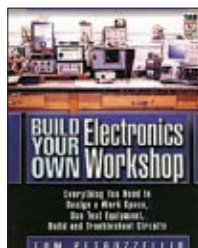


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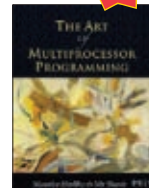
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by Maurice Herlihy and Nir Shavit

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by Joe Pardue

As talked about in the *Nuts & Volts* June issue, "Long Live The Serial Port"

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This is a cookbook for communicating between a PC and a microcontroller using the FTDI FT232R USB UART IC. The book has lots of software and hardware examples. The code is in C# and Visual Basic Express allowing you to build graphical user interfaces and add serial port functions to create communications programs.

### The Virtual Serial Port Parts Kit and CD

(also available, above right)

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### PIC Microcontroller Project Book

by John Iovine

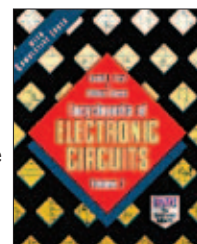
The PIC microcontroller is enormously popular both in the US and abroad. The electronics hobbyist market has become more sophisticated. This new edition is fully updated and revised to include detailed directions on using both versions of the microcontroller, with no-nonsense recommendations on which is better served in different situations. **\$29.95**



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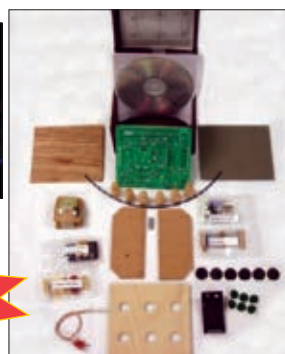
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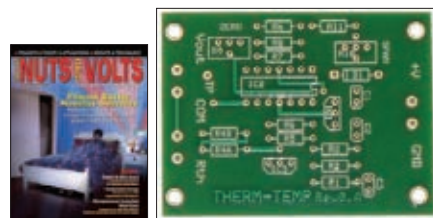
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As seen on the  
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October 2006

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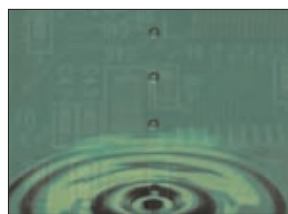
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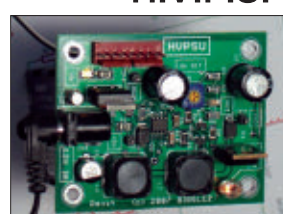
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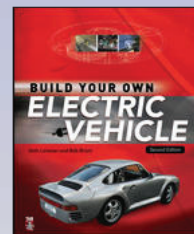
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### Solar Power Your Home For Dummies

by Rik DeGunther

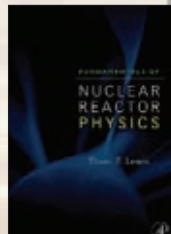
*Publish Date: Dec 2007*

This friendly, hands-on guide is packed with tips for making your home more energy-efficient though solar power---and helping the planet at the same time. You'll see how to survey your home to determine your current household energy efficiency and use, and evaluate where solar power would best benefit you. You'll also calculate what the return on your investment will be before you make any decisions. **\$19.95**



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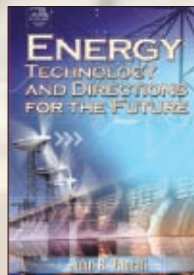


**NEW!**

### Energy Technology and Directions for the Future by John R. Fanchi, PhD

*Publish Date: Feb 2004*

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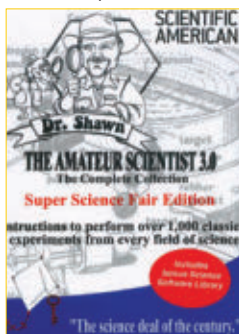


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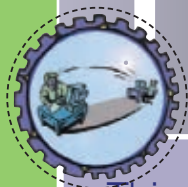
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# TECH



# FORUM

## This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and **NO GUARANTEES WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to [forum@nutsvolts.com](mailto:forum@nutsvolts.com) All *diagrams* should be computer generated and sent with your submission as an attachment.

### QUESTIONS

To be considered, all questions should relate to one or more of the following:

- ① Circuit Design
- ② Electronic Theory
- ③ Problem Solving
- ④ Other Similar Topics

■ Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).

■ Include your Name, Address, Phone Number, and email. Only your Name, City, and State will be published with the question, but we may need to contact you.

■ No questions will be accepted that offer equipment for sale or equipment wanted to buy.

■ Selected questions will be printed one time on a space available basis.

■ Questions are subject to editing.

### ANSWERS

■ Include in the subject line of your email, the question number that appears directly below the question you are responding to.

■ Payment of \$25.00 will be sent if your answer is printed. Be sure to include your mailing address or we cannot send payment.

■ Only your Name, City, and State, will be printed, unless you say otherwise. If you want your email address included, indicate to that effect.

■ Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

## >>> QUESTIONS

### Solar Battery Charger

I'm looking for a circuit for a micro-controller based solar battery charger that can charge a group of four or eight NiMH rechargeable AA batteries.

#12081

**John Weygandt**  
Belleville, IL

### PV vs. EMR

Since solar panels are inherently a diode, would they survive the electromagnetic burst of an EMR weapon?

#12082

**Larry Rheume**  
Eagar, AZ

### SMPS Problem

I recently replaced my SMPS as it was not working. I know the basics about electronics and would like to try to repair it myself (hard disc is not reading). Can someone provide me some information to troubleshoot and repair my unit, if it is possible?

#12083

**Karthik**  
Karnataka

### Variable Brightness Of LEDs

I have two sets of LEDs; eight LEDs in each set. The sets need to turn on alternately. However, I would like the brightness to turn on gradually, then fade out. Then, the second would turn on and off in the same manner.

#12084

**Arsen Dedic**  
Palm Springs, CA

### Timer Circuit

I am looking for a timer circuit to turn on and provide a source of standard 120 VAC house power for a cycle/duration of 24 hours, once every set number of days (e.g., every 2nd day, or every 3rd day, up to every 12th day). The start and stop times would be at the same hour of day.

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#12085

**Ron Sharpe**  
Regina, SK Canada

### Power Tool Batteries

Does anyone have information on how to recell/rebuild power tool batteries? Procedures and suppliers of equipment needed to do it properly?

#12086

**Will Vazquez**  
Forest City, NC

### Webcam Mod

Can I modify a webcam to connect to the RCA connectors on a TV?

#12087

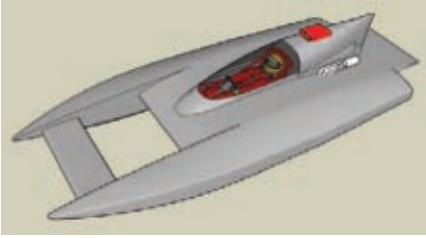
**Ken Hilke**  
New Wilmington, PA

### Testing Components

How can you differentiate a bad transistor from a good one?

#12088

**Koffi**  
Surulere, Lagos



### Automated Pitch Control Of Canard Wing On A Race Boat

I'm trying to figure out the best (and cheapest) way to control a wing (see diagram) on a race boat. It needs to adjust the wing's angle of attack against the boat's angle of attack given varying speeds. I'm also trying to fit all the mechanicals within the wing itself. Servo speed and accuracy is very important as things can go very wrong very quickly at racing speeds.

**#12089** **Tom Nusbickel**  
Santa Ana, CA

### Inverter Not Working

I have an inverter with a megatron card that doesn't work. I've measured the oscillator voltage and it's okay. What can I do?

**#120810** **Juan Garcia**  
Dominican Republic

### Pocket PC Interface

I'm looking for a circuit to interface my Pocket PC through the SD slot. I am trying to come up with an interface to use my HP iPAQ for many different applications ranging from data acquisition to robot control.

Also, regarding the data sync cable and power charging, I have a 22.50V solar cell, max output 120 mA. I would like to build a power supply that connects the USB sync cable from the Pocket PC to the solar cell. I'm not looking at using the data lines on the USB, only the power source. What would be the best circuit design to drop the supply voltage down to the normal voltage that the USB port from my desktop PC provides for charging the Pocket PC?

**#120811** **Richard Forkner**  
Grand Junction, CO

### On Air Digital TV

I am very confused. After the switch to digital TV, can I use the same antenna I am using now for analog

reception, or do I need to modify or replace it to receive digital signals? It seems that everyone thinks that all the signals will be using the UHF band and are selling UHF antennas. Is this true or will some of the stations keep the frequencies they are using now? Is there a frequency listing of the stations after the change over in February? I was under the impression that the VHF/UHF antennas that are being used now would work for HDTV, but I get conflicting advice regarding this. Can someone please give me the straight dope?

**#120812** **Donald Parisian**  
Chicago, IL

## >>> ANSWERS

### [#9085 - September 2008]

*I need a way to find a break and/or weak connection in a radio dog fence.*

*Preferably some kind of signal injector with a radio signal strength meter that can help pinpoint breaks or poor splices in a wire.*

**#1** There are several ways to pinpoint the problem in the wire. The easiest approach is to use a DIP meter in absorption mode or an absorption wave meter to find the spot where the signal gets weak (the absorption wave meter needs a "sniffer coil"). The other way is to modify a receiver and add a signal strength meter to it. Another possibility is Time Domain Reflectometry (TDR), which is frequently used for network cables UTP and STP, unshielded twisted pair, and shielded twisted pair applications. But, it will work on coax, as well (it should work on any medium). The break, short circuit, or any discontinuity such as a change in line impedance will show up as a reflection since the antenna cable forms a "coax cable" of some sort with the surrounding ground. In theory, it will allow you to pinpoint the break if the propagation velocity is known. The soil conductivity varies widely (more than three orders of magnitude) which will affect the impedance, but the approach works well on coax, STP, and UTP. Joseph J. Carr has a whole section on TDR in his

book *Secrets of RF Circuit Design*. The DIP meter and sniffer measurement is well described in Chapter 9 of the *ARRL Data Book*, where you can find a circuit for an amplified wave meter. You may have to build an additional coil for the DIP meter, because most DIP meters only go up to 250 MHz and your dog fence is probably higher than that. I have seen absorption wave meters go up to 450 MHz.

**Walter J. Heissenberger**  
Hancock, NH

**#2** Before doing a lot of testing, it might be wise to replace the batteries in the collar and transmitter and, if possible, test the protected area with a second collar receiver.

As we don't know the operating frequency and modulation scheme of the original transmitter, a test "transmitter" could be used. The matching test receiver needed could be a simple battery-operated AM radio tuned to an unused part of the broadcast band. The test transmitter in this case could be a lab VFO (Variable Frequency Oscillator) that covers the same frequency band (around 1 MHz) and has AM modulation (a 1 kHz tone, for example). If you are unable to borrow this gear, you can construct a very simple VFO or even a crystal controlled oscillator. Modulate its power supply with an equally simple 555 IC type astable oscillator to create your very own low power radio beacon. Either way, the transmitter signal must be made weak so that the test receiver (radio) is not overloaded or pushed in to its AGC limiting.

Start by removing the original transmitter and attaching the dog fence antenna to the signal generator. The radio should easily pick up the signal near this connection. Reduce the signal level as needed so that the radio cannot detect the signal as it is moved by hand away from the transmitter connection. To aid in monitoring the signal level (sound level in the radio's speaker), try connecting an AC voltmeter (or DMM) across the radio's speaker terminals.

By following along the dog fence boundary cable, any damage (breaks, weak connections, or shorts) would



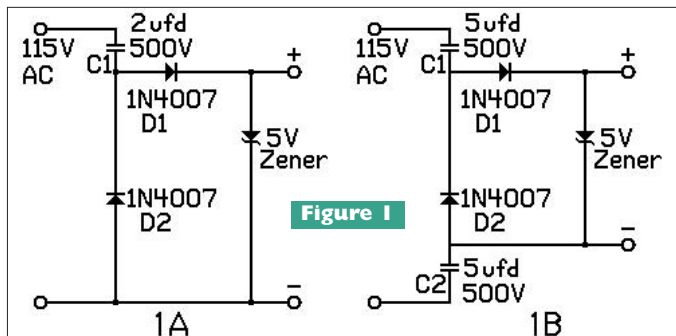


Figure 1

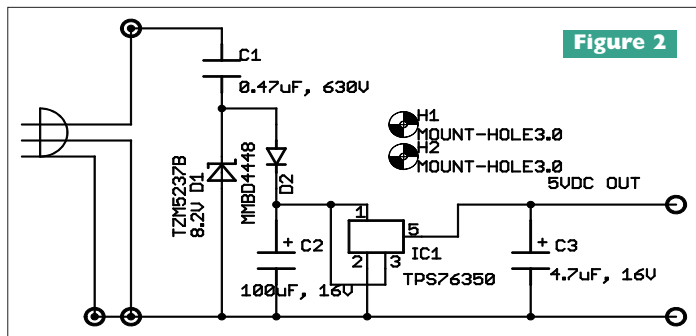


Figure 2

cause the radio to lose the signature signal from the tester transmitter. Repeat the tests after doing any needed repairs and then restore the original transmitter.

**Peter Stonard**  
Campbell, CA

**#3** Dog containment systems (buried wire RF) operate on a variety of frequencies, well below the broadcast band. (Many operate around 18 kHz, but the exact frequencies vary from manufacturer to manufacturer, and some offer selectable channels to avoid interference with neighbors.) This is classified as VLF, and VLF radiates up out of the ground very well.

A tunable field strength meter would be a helpful tool, although very few on the market tune down that far.

As far as breaks in the wire go, usually the buried wire is a solid conductor with relatively thin insulation. Shovel nicks, nicks from poor backfill, etc., tend to cut the insulation and it is just a matter of time before the copper conductor inside turns to green powder (or white powder, in the case of aluminum). In this case, an earth gradient fault locator for buried cables (like the Aqua-Tronics EG-3000; [www.Aquatronics.com](http://www.Aquatronics.com)) will help you in locating the break.

A commercial field strength meter and earth gradient locator will both set you back quite a bit. If it is your own system you are working on, it would be more cost-effective for you to re-bury the line, this time using a stranded cable with a jacket rated for direct burial. If you can't find such cable in your area, you can always bury type UF Romex (like you would run to a lamp post), with the three conductors tied together for redundancy. Any splices needing to

be buried should be coated in pitch or tar, then enclosed in a couple of layers of heat shrink tubing.

**Phil Shewmaker**  
Louisville, KY

#### **[#10081 - October 2008]**

*I am looking for an efficient, physically very small, low parts count circuit to provide a regulated 5V at up to 10 mA output directly from a power line (115 VAC) input.*

**Warning: Non-isolated power supplies present a potentially lethal connection to the AC line and should only be used by persons who completely understand the hazards and appropriate applications.**

**#1** Figure 1A: Very efficient, small parts count, and dirty (hazardous). Two capacitors, two diodes, and a zener. The only power consumed by the circuit is what the zener will be sucking up with no load;  $10 \text{ ma} \times 5\text{V} = 50 \text{ mw}$ . The capacitor will return unused power to the line.

Figure 1B. Very efficient, more parts count, and not quite so dirty. Three capacitors, two diodes, and a zener. One capacitor improves safety.

Keep in mind these circuits without the zener is a voltage doubler, so you will be dealing with 230 volts and our zener sees only 1/2 wave rectification. Double voltage doubles 1/2 wave rectification for total amperage. This circuit is a current source, so treat it with a lot more respect than you would a transformer five volts circuit. For the diodes, as long as this circuit is fully assembled when tested 1N4001s are adequate. Otherwise, 500 volt diodes should be used;  $115 \text{ AC volts doubled is nearly } 330 \text{ volts peak}$ ;  $1.414 \times 115 \times 2 = 325 \text{ volts}$ .

Basic formula  $X_c = 1 / (2\pi F C)$ . Therefore  $C = 1 / 2\pi F X_c$ .  $X_c$  is the desired impedance to the frequency ( $F = 60 \text{ Hz}$ ).  $R = E / I$ ,  $R = 115 / .01 = 11,500 \text{ ohms}$ ,  $X_c = R$ .  $C = 1 / (6.28 \times 60 \times 11,500) = 2.3 \mu\text{F}$ . If you do not mind a little less amperage, use a  $2 \mu\text{F}$  cap for Figure 1A, or put a  $.5 \mu\text{F}$  cap in parallel with the  $2 \mu\text{F}$  cap. Two  $5 \mu\text{F}$  caps for 1B.

For parts, you could take a bad compact florescent bulb base apart. Inside are 1N4007 diodes (1,000V 1A), 200 volt capacitors at  $10 \mu\text{F}$  for 60w and  $20 \mu\text{F}$  for 100 watt equivalent bulbs. The base case is plastic; the groove around the base is a four snap tab fitting. With a little persistence and a small screwdriver, it will come apart.

**Alonzo E. Fuller**  
Sweet Home, OR

**#2** There was no requirement in the question that the output be isolated from the line, so I designed this capacitive coupled supply (Figure 2.) The safety ground is connected to neutral so there is no chance that common will be hot. The TPS76350 has a maximum input rating of 10 volts; that is one reason for using an 8.2 volt zener at the input. The layout (Figure 2A) is 1.15 inches by 1.35 inches, including two mounting holes.

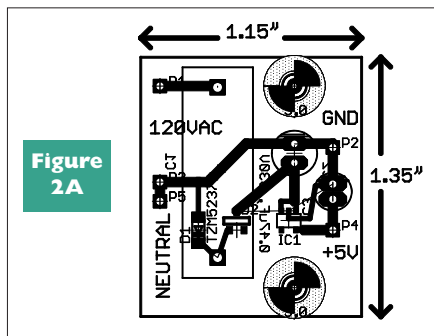
#### **Parts List:**

C1	5989-630V.47-F	\$1.74
D1	78-TZM5237B	\$0.03
D2	512-MMBD4448	\$0.06
C2	140-XRL16V100-RC	\$0.08
C3	140-XRL16V4.7-RC	\$0.06
IC1	595-TPS76350DBVR	\$0.88

All Mouser part numbers.

**Russ Kincaid**  
Milford, NH

**#3** Bryan, get your soldering iron out and download Microchip App



note AN954. It has just what you want (with no transformer)! You can get it at [www1.microchip.com/downloads/en/AppNotes/00954A.pdf](http://www1.microchip.com/downloads/en/AppNotes/00954A.pdf) or <http://tinyurl.com/no-xformer> for a shorter path.

The schematic in Figure 1 (of AN954) uses five small parts and uses a capacitor to limit the current and drop the excess voltage that the zener and your 10 mA load doesn't use.

Figure 5 uses only four. This circuit is like Figure 1, but uses a resistor instead.

Figure 10 = Figure 1 but uses eight parts as it has more safety features built in.

Figure 11, likewise, is the same as Figure 5 using nine parts.

And Figure 12 uses four parts and uses a bridge rectifier for better efficiency and output voltage stability.

Have fun, safely!

**Brian German**  
**Thief River Falls, MN**

**[#10082 - October 2008]**

*I need to monitor when my sump pump in the basement goes on and off. The pump draws 10A @ 120 VAC.*

**#1** If your sump system has a separate pump and float switch plugs, this is easy. The float switch plugs into the wall and then the pump plugs into the back of the float's plug. Simply unplug the pump from the switch, add a multi plug adapter (one plug to three) and plug the pump back in. In one of the remaining plugs, add some sort of device that makes a loud noise when powered on. You could plug in an AC adapter and run low voltage wiring to another part of the house to activate a flashing light and/or some sort of siren or bell. Cost is about \$2 plus what you decide to spend on the alarm device.

If your sump system has a single plug, you can get a device from Sears called a "Craftsman Auto Switch" (Sears item #00924031000) Mfr. model #24031). Other places that sell power tools have these controllers but I'm familiar with the one from Sears. This device plugs into the wall outlet and you plug your control equipment (such as a table saw) into the MASTER outlet. There are two slave outlets that supply power to such devices as lights or vacuums. When you turn on the saw, the vacuum cleaner is automatically powered on, as well. In this case, you plug your pump into the MASTER outlet and using the same concept as before, plug in an alarm device to one

of the other outlets. When the pump turns on, it will activate the other device you have plugged in the SLAVE outlet. Cost is \$20 plus what you spend on the alarm device.

There are also computer grade power strips called "Smart Strips" that do basically the same thing as the Craftsman Auto Switch. The difference is the Craftsman device was designed with high current motor loads in mind. Perfect for your situation.

The first solution has the attraction of being cheaper. But it will only tell you if the pump switch is on and not if the sump motor is running. The second – while more expensive – will detect if the pump is running.

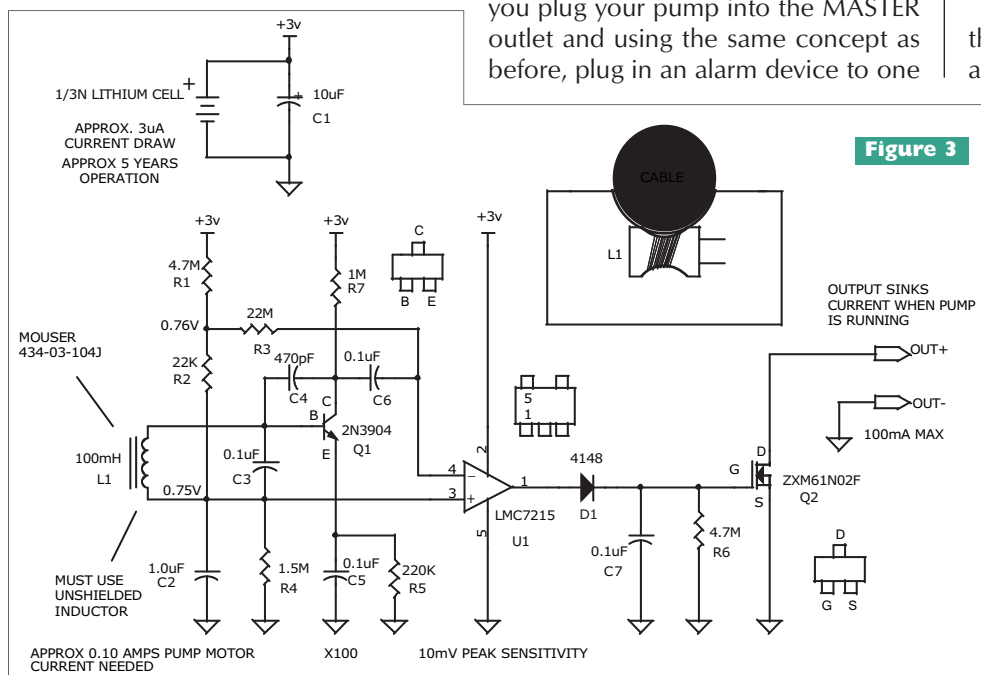
**Tim Naami**  
**Poplar Grove, IL**

**#2** Dave Johnson's website provides the perfect answer. **[www.discovercircuits.com/DJCircuits/pumpmotormon2.htm](http://www.discovercircuits.com/DJCircuits/pumpmotormon2.htm)**

The circuit (Figure 3) can turn on a light or sound a beeper, whenever an AC line powered pump motor turns on. It is designed to detect the motor current using a small inductor placed on the outside of the motor's power cable. No direct wire contact is needed.

**Wesley K. Miller**  
**Dillsburg, PA**

**#3** A GFCI receptacle contains all the electronics you need, except for an LED and a 10K resistor. It can be modified to light the LED anytime the pump runs. The modification consists of opening the circuit at the SCR that energizes the solenoid and placing a 10K resistor and LED in series across the opened circuit. The one I just tested required disassembling the GFCI, cutting one circuit trace, drilling two holes in the back of the GFCI, running two wires through the holes and soldering them to the circuit board, and reassembling the GFCI. The LED and resistor are connected to the wires. Disassembly and reassembly must be done with care so that nothing is damaged. When reassembling, there are two movable contacts





that must be gently pressed back with a small screwdriver or other tool to allow the circuit to be fully pushed in to the GFCI housing.

All GFCI receptacles work by detecting an imbalance of current on the hot and neutral wires. You can create the imbalance by wiring the input to the GFCI with the hot wire connected to the LINE terminal and the neutral wire connected to the LOAD terminal, and plugging the pump into the receptacle. That way, when the pump turns on, current flows through the GFCI circuit on the hot wire, but bypasses the circuit on the neutral wire, so an imbalance is created. Normally, that would energize a solenoid in the GFCI and open the circuit, but your modification prevents that. Instead, the LED lights, and stays lit until the pump turns off.

The wiring in GFCIs can differ between models or manufacturers, so you will need to determine how yours is wired. A representative example can be seen on page 5 at: <http://www.fairchildsemi.com/ds/RV/RV4145A.pdf>

Installing a modified GFCI in permanent branch circuit wiring would violate electrical code. Instead, install your modified GFCI in a project box or electrical junction box that is wired as an extension cord.

**Ed Schick**  
Harrison, NY

#### **[#10083 - October 2008]**

*I have an X10 lighting system in my home that used to work flawlessly, using X10's "Active Home" software to control the yard lights. Over the last year, some zones work intermittently and some not at all. I've tried to find any electrically noisy appliances that may be on when the system gets flakey, but have not seen any consistent pattern that might be causing the problem. I do know that the new pump motor for the pool equipment creates problems when it's on, but it shuts off hours before the lights come on (or try to).*

**#1** I doubt the pool pump is to blame — it uses a capacitor-start single-phase AC induction motor which may dim the lights briefly when fired up

(much as heat pumps, A/C, electric dryers, or any other heavy current load would). A large motor may cause a single brief power line glitch when up to speed and the start-winding cuts out (usually within five seconds of start).

If you have (or can borrow) another X-10 transmitter, try to isolate the problem to the Tx, Rx, or the PC running the HA software. Have you moved the place where the transmitter plugs in to the house wiring? Did any home remodeling or electrical work shift the wiring in the breaker panel?

The transmitter and X-10 controllers must be on the same "leg" or phase of the AC wiring (i.e., L1 or L2), preferably on the same branch circuit (breaker) for reliable communication over the power line.

**Peter Stonard**  
Campbell, CA

**#2** The first thing I would check is the interface from your computer. See if there is another port on your computer with which you can connect to the interface. Or try to borrow another interface — it may have been killed by a power line spike. Where I live, we get lightning with storms that can kill electronics systems. Try reloading the Active Home software.

Next: Have you changed operating systems on the computer (XP to Vista)? If you have, try reloading the old system.

If you have a wireless Internet server, it can cause some interference problems. Try turning off the wireless part of it. My Netgear WGR614 can cause interference with cell phones and has the ability to enable or disable the wireless function.

**Bill Roberts**  
Hanover, MD

**#3** Sometimes the saved Active Home (AH) files become corrupted. My bedroom lights would randomly turn on at different times every night! When I destroyed my saved AH files and rebuilt them from scratch, the problem went away.

Also, I'd like to recommend trying a couple products that have given

me consistent and reliable X10 communication signaling in my house without any weird shenanigans.

*PZZ01 Blocking Coupler.* Keeps your X10 signals inside your house and keeps your neighbor's signals out.

*Plug-In Phase Coupler.* Some of these devices plug directly into the 220 VAC outlet meant for your clothes dryer and have a pass-through design so you can still plug in your dryer.

**Joe Kissell**  
Gardner, KS

**#4** In most homes, power is brought in to the house via a center tapped transformer on the street. The outer terminals provide 240V for the stove and dryer and the center tap provides the neutral which gives you two phases of 120V for everything else. In the X10 system, your transmitter will transmit the signals on whatever phase it is plugged into. It can easily talk to other X10 devices on the same phase wire but in order to talk to devices on the other phase, the signal needs to go all the way back through the transformer on the street to be coupled to the other phase.

This can severely attenuate the signal, resulting in unreliable operation of X10 devices not on the same phase wire. My guess is that the poor signal quality on the other phase results in X10 devices that work intermittently. The easiest way to test this is to wait until you are experiencing problems and then turn on your electric oven. The large 240V element in the oven will act as a resistor across the two phases. This should allow the signal from X10 to pass easily from one side to the other. If after turning on your oven, all the X10 devices work perfectly, then you have a phase coupling problem.

The permanent solution to this is to insert a 0.1 micro farad capacitor across the 240V stove breaker in your electrical panel. Make sure you turn off the main power before doing this and make sure to use a capacitor that is rated for AC and "Across the line" use. The capacitor that I used was Digi-Key part number P10523-ND.

**Colin Stewart**  
Ontario, Canada



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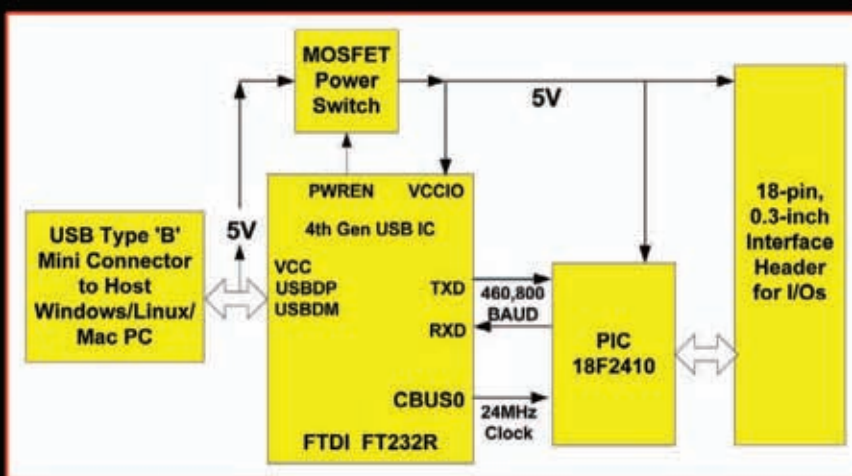
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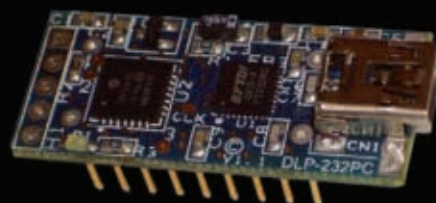
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57BYGH405	NEMA 23	20kg.cm/277oz.in	\$28.90
85BYGH450B-03	NEMA 34	48kg.in/665oz.in	\$68.00
85BYGH450C-03	NEMA 34	63kg.cm/874oz.in	\$89.00

Part #:	Dim:	MicroStep:	Price:
XCW220	100 x 61 x 19mm	1(200), 1/2(400), 1/4(800), 1/8(1600)	\$39.95
CW230	115 x 72 x 32mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800)	\$48.50
CW250	140 x 94 x 45mm	1(200), 1/2(400), 1/8(1600)	\$54.90
CW860	147 x 97 x 30mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800), 1/128(25600), 1/10(2000), 1/125(5000), 1/50(10000), 1/250(50000)	\$96.00

## CSI-2901 LEAD Free Soldering Station

Compatible with all lead-free alloy solder and standard solder. Excellent thermal recovery without a large increase in tip temperature. Utilize an integrated ceramic heater, sensor, control circuit and tip for greater efficiency, along with a highly dependable 24V output transformer. The effortless replacement of soldering tips makes for quick changes and the optional shut-down setting turns the unit off after 30 min. of idle time. Various tips are available at our Web Site!



Item #

**CSI-2901**

- Power Consumption: 70W
- Output Voltage: 24VAC
- Temp Range: 200-480°C/ 392-896°F

Reg Price \$59.00

**SALE!**  
**Only \$39.00**

## Dual Output DC Bench Power Supplies

High stability digital read-out bench power supplies featuring constant voltage & current outputs. Short-circuit & current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance & long life. All 3 Models have a **1A/5VDC Fixed Output** on the rear panel.



Item #:	Price 1-4	Price 5+
<b>CSI3003X-5</b> 0-30V/0-3A	\$119.00	\$112.00
<b>CSI5003X5</b> 0-50V/0-3A	\$127.00	\$119.00
<b>CSI3005X5</b> 0-30V/0-5A	\$129.00	\$122.00

## 4.5 Digit, True RMS Autoranging Bench Top Multimeter

A Super Value for a Bench Top DMM. Loaded with features and specifications of higher end units, at a very modest price.

- Digital & Analog display, 22000 count and 44 segment bar graph
- Autorange and manual range
- DCV 1000V in 5 ranges
- ACV 700V in 5 ranges
- Plus AC/DC current, resistance, capacitance, logic & temp.
- RS232 I/F & Windows software



**New!**

Item #

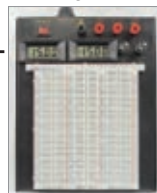
**CSIMS8040**

**Only \$129.00!**

## PBB-272A Powered Breadboard w/ LCD Voltage Displays

Provides the user with a quick and efficient system for breadboarding electronic circuits. Comes with three regulated power supplies along with a deluxe, easy-to-use breadboard. **Two LCD's conveniently show the 0-15 positive and 0-15 negative outputs.**

- 5 Distribution Strips (500 tie points)
- 3 Terminal Strips (1890 tie points)
- 4 Binding Posts
- One Ground
- One 5VDC (1 AMP) Constant Power
- One 0 to +15VDC (500mA) Variable Power
- One 0 to -15VDC (500mA) Variable Power
- 110VAC Input Power,  $\pm 10\%$



Item #

**PBB-272A**

**Only \$89.00!**

## Special Bundle Deal !!!

Order Item #

**PBB-272ABUNDLE**

(Includes a PBB-272A and a CSI2205D)

**Special! \$99.00!**

## CSI-2205D 4,000 Count True RMS Hi-Accuracy DMM

The CSI2205D Micro Control Unit auto-ranging DMM is **UL Listed** and designed for measuring resistance, capacitance, DC & True RMS AC voltage, DC & True RMS AC current, frequency, duty cycle and temperature, along with the ability to test diodes, transistors and continuity. A special feature included is the Auto Test Lead Input Indication Technology. This will ensure that whenever you switch functions on the DMM, the proper positive port LED will light indicating where to plug the red test lead into so that no mistakes can be made by the user. It even goes so far as to give a warning tone if you do plug the lead into the incorrect jack!

A very helpful feature for the novice and even for the experienced user who is using the meter in less than ideal lighting conditions. Overall, we find this to be a meter that compares very favorably with much higher priced competitors on the market today!



**HOT Item!**

Item #  
**CSI2205D**

**Only \$59.00!**

## Soldering Station w/ Ceramic Element & Separate Solder Stand

- Ceramic heating element for more accurate temp control
- Temp control knob in F(392° to 896°) & C(200° to 489°)
- 3-prong grounded power cord/static safe tip
- Separate heavy duty iron stand
- Replaceable iron/easy disconnect
- Extra tips etc. shown at web site



Item #

**CSI-STATION1A**

**\$39.95!**

## Also Available w/ Digital Display & Microprocessor Controller

Item #

**CSI-STATION2A**

**SALE! \$44.95**



## ESD Safe CPU Controlled SMD Hot Air Rework Station

The heater and air control system are built-in and adjusted by the simple touch of the front keypad for precise settings. Temperature range is from 100°C to 480°C / 212°F to 896°F, and the entire unit will enter a temperature drop state after 15 minutes of non-use for safety and to eliminate excessive wear.



**SALE! \$129.00**

Item#

**CSI825A++**

## Our Premium All in One Repairing System

- Combines the function of a Hot Air Gun, Soldering Iron and a Desoldering Gun.
- Microprocessor controlled ESD safe unit with all digital display
- Desoldering tool comes with zero crossing circuitry preventing electrical surges and equipped with air cylinder type strong suction vacuum pump.
- The 24V soldering iron is compatible with the compound tip design.
- Uses lead-free or standard solder.



**SALE! \$199.00**

Item#

**CSI-9000**

## Triple Output DC Bench Power Supplies

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1 fixed output @ 5VDC@3A
- Stepped Current: 30mA +/- 1mA



Item #:	Price 1-4	Price 5+
<b>CSI3003X3</b> 0-30Vx2@3A	\$198.00	\$193.00
<b>CSI3005XIII</b> 0-30Vx2@5A	\$259.00	\$244.00

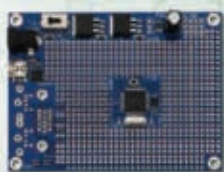


# W I S H L I S T

Eager to get programming or to supplement your electronics projects? Parallax has what you need!



**StampWorks Experiment Kit** (#27297; \$289.99) 35 great BASIC Stamp projects on the Professional Development Board.

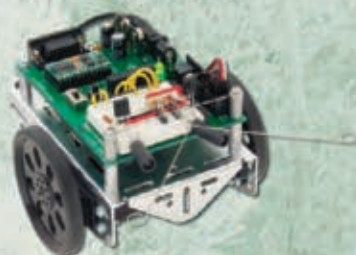


**Propeller Proto Board USB** (#32812; \$39.99) Perfect for dedicated projects! Requires only a USB A to Mini-B cable for the PC programming connection.

**Sensor Sampler Kit** (#28028; \$179.99) A collection of our nine best selling sensors.



**Propeller Professional Development Board** (#32111; \$169.99) This feature-rich board sports built-in peripheral connectors to easily tap into the Propeller chip's multi-processing power and flexibility.



**Boe-Bot Robot Kit** (Serial/USB #28132; \$159.99) Our best-selling robot is an excellent introduction to electronics, programming, and sensor-based navigation. Versatile and expandable with our selection of Robotics Accessory Kits.

**HYDRA Game Development Kit** (#32360; \$199.99) Develop games, graphics, and media applications with this Propeller-powered console.



**BASIC Stamp Discovery Kit** (Serial/USB #27207; \$159.99) Our most complete starter kit for microcontroller programming and experimentation.

**BASIC Stamp 2 module** (#BS2-IC; \$49.00) A single board computer that runs Parallax PBASIC language interpreter in its microcontroller. Ideal for beginners yet quite powerful, with a vast resource base and sample code.



Order 24-hours a day at [www.parallax.com](http://www.parallax.com) or call our Sales Department toll-free at 888-512-1024 (Monday - Friday, 7:00 a.m. - 5:00 p.m., PT).

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